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Smelting Phosphorus. ELSEWHERE in our columns this week will be found an account of the electrical process of smelting phosphorus, which was briefly referred to in our cable dispatch recently. The present chemical process for the separation of this element from its compounds is, essentially, the reduction of phosphorus from its oxide by carbon. The phosphoric acid which serves as a base for operations is, however, somewhat troublesome to prepare, and the temperature required for the final reduction is undesirably high, not infrequently causing the loss of the phosphorus through breakage of retorts. The works described in our article are on a considerable scale, and the electrical apparatus is of large capacity. The process, roughly speaking, is feeding the raw material into something very like the Cowles furnace, and then condensing the vaporized phosphorus in the ordinary way. The great advantage of all these processes of electrical smelting is that the heat is generated right at the point where it is wanted; it is not wasted in burning up the retorts, but is applied to the very centre of the mass of material to be smelted, and works outward from there, bringing the highest temperature not on the retort but on the material itself. This, aside from the enormous heat attained, is an immense advantage, inasmuch as in all smelting processes requiring very powerful furnaces trouble is usually met from the destruction of the retorts. By the electrical process damage of this kind can be reduced to a minimum, and at the same time the work can be cleanly and economically done. The current employed in this particular process is alternating, and the action does not therefore at all partake of the nature of electrolysis, but is a pure smelting effect, such as is obtained in some of the electrical aluminium processes.

Electrical Cable Testing. IN the current number we continue an important paper on electrical cable testing by an engineer of long experience in this particular class of work. The subject is an interesting one, both on account of the delicate nature of some of the measurements necessary and their really great practical importance. On overhead lines the locating of a fault by electrical means is only a convenience, but in underground cables it is a necessity, for in the absence of such information as to the position of a break in the mains, days of work and considerable expense may be necessary in order to search it out. When, however, as in one example given by Mr. Fisher, a fault in a telephone cable nearly a mile long was located within four feet of its actual position, we may form some idea as to the practical accuracy of the methods described and the commercial value of their application. The methods of electrical testing under such circumstances have, for the most part, long been known, but they are not easy to get together in a single paper and in such form that they can be readily applied by practical men. To this end Mr. Fisher's papers have been, so far as possible, non-mathematical, and the descriptions of apparatus and methods have been made plain and simple so that they can be understood by the every-day electricians for whose use they are particularly intended, and to whom we believe they will prove of no small value.

An Ingenious Electric Meter. OF making many meters there is no end, and the amount of ingenuity that has been fruitlessly spent in overcoming the almost innumerable difficulties that have to be met is something prodigious. In the new instrument described elsewhere in our columns and devised by Prof. John Perry, there are, however, features of unusual interest that would commend it to notice even were it less simple and accurate than it is. It belongs to the class of motor meters of which the Thomson wattmeter is perhaps the example best known to our readers. In Prof. Perry's instrument, however, the retarding force is not due, as in the instrument just mentioned, to a field derived from permanent magnets, but to the development of Foucault currents in the armature during its rotation in a systematically irregular field. The armature itself, instead of being wound with wire, is nothing more than a bell-shaped shell of copper revolving in mercury. By this device the current is supplied to the armature without the necessity of brushes, and inasmuch as the copper bell is almost completely immersed in mercury the only resisting force due to the latter fluid is that produced by almost pure fluid friction, which is practically directly proportional to the velocity for very low speeds. In any case this friction, as a factor of the retarding force, is of very little account compared to the effect of the Foucault currents, which is directly proportional to the current through the armature and to the number of revolutions per second. The field magnet is shunt wound and nearly saturated, so that a variation of a few volts in the electrical pressure will not produce much inaccuracy in the readings. The results given speak for themselves; in a 100 ampère meter an error of only one per cent. from two ampères to the utmost limit of its load certainly leaves little to be desired, and Prof. Perry may well be congratulated on so simple and effective a solution of the direct-current meter problem as the present instrument.

Electrical Evaporation. IT has long been known that when an electric spark is passed between metallic terminals in a high vacuum a certain amount of disintegration goes on, resulting often in the formation of a metallic film over the interior surface of the tube. This phenomenon has been taken advantage of in the making of small mirrors for physical apparatus and has proved very successful. In a paper by Prof. William Crookes, F. R. S., published elsewhere in these columns, this question of electrical evaporation is taken up in great detail and some extremely interesting facts have been unearthed. First among them is the extraordinary influence of the negative pole under the circumstances mentioned. One would naturally suppose, at first sight, that the action would not be dissimilar to that which takes place in arc lamps, where the positive carbon is subject to rapid disintegration; but on the contrary, the positive terminal of such a vacuum tube is very little affected, the evaporation being almost entirely from the negative one. On testing a considerable number of metals Mr. Crookes found that their volatility under these circumstances not only was very variable, but bore no particular relation to the order of their relative melting points, to their atomic weights, or to any other well-known constants. The amount of volatilization that could be produced was very considerable especially when the metals experimented on were raised artificially to a somewhat high temperature. The facts brought out are most striking, and a continuance of the experiments may not improbably cast some light on what is almost an inexplicable fact in electrical action, that is, the peculiar differences that exist under certain circumstances between positive and negative electrification. It is a pity that Mr. Crookes did not, among his other experiments, try the effect of changing the medium in the exhausted vessels. What would be the effect, for example, of volatilizing metals electrically in an atmosphere of hydrogen, or of carbonic acid, instead of rarified air? There are some reasons for supposing that the difference in action between the positive and negative electrification may depend, to a considerable extent, on the dielectric, and this point is apparently one that might be settled by experiments along the very line which Mr. Crookes is now pursuing. He is certainly a master of technique in this delicate and difficult class of work, and we hope that he may have an opportunity to pursue his investigations still further.

High Frequency Alternations. AT last, after protracted delay, Mr. Nikola Tesla's paper before the American Institute of Electrical Engineers at its annual meeting is ready for publication. The period of waiting, however, is more than compensated by the finished form in which Mr. Tesla's research appears. It is hard in any reasonable space to give an adequate idea of the suggestiveness of the very remarkable work that he has done. It contains not only hints bearing on the most occult portions of theoretical electricity, but also gives promise of future commercial importance. To search out the nature of the forces that appear in electricity and magnetism is the most fascinating, as it is perhaps the most difficult, problem before the scientific man of to-day. During the past ten years not a few brilliant minds have been turned toward its solution, but as yet very little has actually been accomplished, although much is to-day promised. The clever speculations of Lodge, and the magnificent experimental work of Hertz and others, have thrown a flood of light on portions of the subject that has heretofore been wrapped in profound darkness. Nevertheless, as Mr. Tesla very properly suggests, much of this work is rather ingenious than satisfying. To a certain extent one cannot help feeling that it bears some resemblance to the theory of epicycles advanced by the early astronomers; it was a clever conception, and by the very simple device of subdividing the motions, as Lodge subdivided the ether, it was possible to account for very many of the curious anomalies in planetary motion. It remained for Kepler, to show that the epicycles were only a complicated system for translating into terms of circular motion the elliptic orbits of the heavenly bodies. In a similar way we may find, indeed probably shall find, that the machinery of positive and negative electricities, of a subdivided ether and atomic charges, are merely modes of expressing certain phases of a reality by no means so complicated. Perhaps it may be that we speak now of positive and negative electricities much as one would have spoken 40 years ago of the north and south poles of a solenoid, and similarly it is probable that the hypothesis of an atomic charge is only another way of asserting the dynamical equivalence of all atoms of a particular kind. As regards the commercial possibilities of Mr. Tesla's work, it is not easy to predict anything with certainty; it is a promising direction in which to work, but the difficulties in the way are many. Chief among them is that of distributing currents of high frequency, at least of as high frequency as were employed by Mr. Tesla in his experiments. For such currents an ordinary solid wire is but poorly adapted on account of its high self-induction, and one is confronted by the possibility of hollow wires, of cables composed of thin strips, and other forms of conductor that are not altogether attractive from a commercial point of view. And then comes the condenser, the most beautiful of all transforming devices, provided it can be made cheap and durable; and after all this comes the question of suitable lamps for utilizing the currents after they are obtained and distributed. From the standpoint of economy the vacuum tube type shown by Mr. Tesla is by all odds the most promising. Lamps with filaments brought to incandescence by induced currents would have no special advantage in economy of illumination over those made in the ordinary way, but if it were possible to obtain a mass of luminous gas that would give a clear and steady light it might be that a far greater percentage of luminous radiation could be procured from it than has ever been obtained from a mere heated solid, and this is the direction in which work is needed. Prof. Langley has shown that luminous radiation almost pure, and therefore of maximum efficiency, is emitted by the firefly. The incandescent lamp, on the other hand, gives, so to speak, a minimum of radiant illumination with a maximum of heat rays. Mr. Tesla is working industriously on the problem of substituting for the last-mentioned inefficient arrangement some form of induction tube in which one may at least simulate in character the glow of the firefly, and thus obtain, from a given amount of electrical energy, perhaps a dozen times more light than has ever yet been secured. The field of investigation is a most fascinating one and promises great things in the future. Meanwhile, Mr. Tesla's present paper gives an admirable summary of the results he has attained up to date and the varied course of his beautiful investigations.

Latest Foreign Electrical News.

(By cable from our own correspondent.)

London, July 6, 1891.—Mr. H. Vernon Boys showed at the meeting of the Physical Society, on June 26, one of the most beautiful of his numerous ingenious electrical apparatus. It was nothing less than a pocket electrometer provided with one of the quartz fiber suspensions with which Mr. Boys has previously obtained such remarkable effects. The instrument, in spite of its small size, has a wide range. The needle is composed of platinum and zinc, and is charged by this contact difference of potential to eight-tenths of a volt instead of being separately charged to about 2,000 volts. Its period of swing is 35 seconds. The quartz fiber has appeared in a large number of other pieces of apparatus of Mr. Boys' devising, notably as a galvanometer suspension, as part of the apparatus for demonstrating and measuring the attraction of gravitation, and in all sorts of delicate measuring instruments. The present, however, is one of the cleverest of Mr. Boys' numerous inventions.

The peculiar property of the quartz fiber that gives it such value in measuring instruments is its very regular elasticity. It is entirely free from the irregular viscosity and tendency to kicks and twists that appear in silk fiber or spider threads, and, besides, is relatively strong and of very small weight and diameter. The fibers are prepared by softening quartz before the oxyhydrogen blowpipe, and then attaching a part of the softened mass to a minute arrow, which is then shot out, drawing the fiber after it.

The Eastern Telegraph Company has given notice that reduced tariffs to the Mediterranean and eastern points have been agreed on by the International Telegraph Conference at Paris. This tendency toward reduction of rates has been going on gradually for some time. It was only a short time ago that we reported a reduction of the rates to Australia, and now it seems likely to become general.

During the past week there have been very many severe thunderstorms, accompanied by a great deal of damage and some loss of life.

ELECTRICAL WORLD PORTRAITS.—XXVII.

PROF. JOHN PERRY.

One of the most indefatigable workers in applied electricity to-day is Prof. Perry, who is perhaps best known by the splendid work that he has done in connection with his friend and colleague, Prof. Ayrton. Although that intellectual partnership is now concluded, neither of the parties to it have ceased one whit from the immense activity that they have exercised formerly, and no better evidence of this can be adduced than the beautiful meter described elsewhere in our columns this week.

Prof. Perry was born 41 years ago in a little village in Ulster, and was educated principally in Belfast. As a boy he was apprenticed to a foundry firm, and went through the drawing office and shops, but afterward matriculating at Queen's College, Belfast, after a scholastic career marked by many brilliant successes he graduated with the first honors and the Peel prize for mathematics in 1870. He became almost immediately afterward lecturer in physics at Clifton College, and remained there four years, building up a physical laboratory and workshops. During this period he published an elementary treatise on steam that brought him almost immediately into notice. In 1874 he was secretary of the mathematical and physical section of the British Association for the Advancement of Science, and became Thomson scholar and honorary assistant to Sir William Thomson in Glasgow University.

Prof. Perry's first scientific paper was on conductivity of glass as dependent on temperature, and was read before the Royal Society of London in 1875. In that year he went to Japan as professor of engineering in the Imperial College of Engineering, and there formed the association with Prof. Ayrton which has been productive of so much excellent work. During the next four years so large an amount of electrical work was turned out that Clerk Maxwell once quizzically remarked that the electrical centre of gravity had been removed to Japan.

Since 1876 Profs. Ayrton and Perry have published nearly 50 important joint papers, of which a few are the following: "The Specific Inductive Capacity of Gases," "On Electrolytic Polarization," "Resistance of Galvanometer Coils," "Ice as an Electrolyte," "Heat Conduction in Stone," "Contact Theory of Voltaic Action," "Ratio of Electric Units," "On Electromotors and Their Government," many papers "On Electrical Measuring Instruments," "On the Gas Engine," "Magnifying Spring," "Self and Mutual Induction," and many other electrical subjects.

In 1879 Prof. Perry returned from Japan and organized the important electrical works of Clark and Muirhead, and from that time has been assiduously engaged in practical electrical work. In 1881 he gave before the Society of Arts an extremely brilliant lecture on the future development of electrical appliances that has since been published as a separate book. At about the same time he began active work in the City and Guilds' Institute, and formed the system of technical examination in the course of mechanical engineering there. In 1882 he delivered a course of Cantor lectures on hydraulic machinery, and at that time was appointed professor of mechanical engineering and applied mathematics in the Finsbury Technical College. Prof. Ayrton and Prof. Perry were intimately connected with the early work of the Faure Accumulator Company, and arranged a very large amount of electrical work in that line. Besides this they were steadily engaged in the invention of electrical appliances, and have turned out an amount of work that has been simply prodigious. Among the large number of the important appliances that have been the result of their ingenuity are the spiral spring ammeters and voltmeters, the hot-wire voltmeter, the secohmmeter, the ergmeter, several types of small electromotors, one or two very neat forms of transmission and absorption dynamometers, a large number of details with reference to the governing of dynamos and motors, and, finally, the elaborate railway system belonging to the Telpherage Company. On the death of the lamented Prof. Fleeming Jenkin, Prof. Perry became engineer of the Telpherage Company and set up the first considerable line that they instituted.

In 1889 the Ayrton and Perry partnership was formally dissolved, and since then the two investigators have been working independently, but with no less energy than before.

Prof. Perry is a Fellow of the Royal Society, doctor of science and master of engineering, associate member of the Institution of Civil Engineers and of the Institution of Electrical Engineers, and secretary of the Physical Society. He has been during the last decade, and is to-day, one of the most energetic, active and brilliant workers in applied electricity, and unless the beautiful meter he has just invented is a deceptive indication, the next few years will make his name even more familiar than at present to electrical engineers.

PROF. JOHN PERRY.

Rules for Increasing the Efficiency of Telephone Service.

BY GEO. S. MAXWELL.

At the last meeting of the telephone convention an arrangement of the different departments of a telephone company was suggested in order to secure the best results. This was to be done by making the employès of each department responsible to their immediate superiors.

I am thoroughly convinced that this is the only way to secure good service, and in no place is it so much needed as in the operating department. Unfortunately in a great many instances recruits for this department are appointed, not on account of any particular ability, but on account of their political influence. This renders the service unastisfactory, as the operator soon understands her position and violates rules with impunity, knowing that her political backing is strong enough to prevent her discharge.

After careful investigation and comparison I am led to believe that with the following rules adopted it would be possible to get the best results in the operating and trouble department:

Politics should have nothing whatever to do with employés.
Operators should be directly responsible to the chief operator.
They should answer calls by saying "Number, please," "Line busy" or "Can't call," as the case may be.
In no case should they be allowed to hold conversation with subscribers.
They should not be allowed to receive complaints or to test lines or instruments. All such calls should be at once connected with the trouble department.
Inquiries for information should be connected with the chief operator or monitor.
Operators should not be allowed to talk across from one to another or to "pass connections."
Operators should keep the telephone to the ear when on duty.
They should sit facing the table and transmitter.
The subscriber should call by number as follows: 1144 should be spoken "one one-four-four," thus preventing mistakes.
Favoritism should be shown no one.
Strictest business forms and politeness should be observed at all times.
The chief operator should be the sole judge of the fitness of operators, and should have full power to dismiss them for incapacity or violation of the rules.
Punishments for violation of rules should be meted out without fear or favor and should be: reproof, reduction in rank and pay, or dismissal.

A system of careful selection should be adopted, and any operator found unruly or incompetent should be promptly dismissed. In a short time by this plan a force could be secured that was in every way reliable. With these rules adopted the efficiency of the service could be increased one hundred per cent. One half of the operator's time that is now spent in frivolous conversation with her sweetheart or certain subscribers on her section that she favors would be utilized in answering the calls of other subscribers that are forced to wait until the sweet-voiced operator concludes her conversation with the soft-headed dude, and, like Dr. Jekyll and Mr. Hyde, makes a lightning change and snaps you up with, "What do you want?" spoken with the air of a vixen, or says: "Stop that ringing. If you want a connection don't ring your bell through eternity!" and immediately proceeds to cut you off, and you hang up your telephone in despair. I have been in the telephone business for the past eight years, and in no other department do I think there could be so great an improvement made by the adoption and enforcement of such simple rules.

The Work of the Late Prof. Weber.

It may be of interest to our readers to know something more of the career of Wilhelm Edouard Weber, whose death was announced in our brief cable dispatch of last week, in which, by the way, his initials were wrongly given. Wilhelm Edouard Weber was born Oct. 24, 1804, at Wittenberg, and was therefore more than 86 years old at the time of his death. His name does not appear in the annals of electrical science in any prominent way until the period of electrical activity that followed the brilliant work of Gauss and Faraday. In 1831 he was professor of physics at the University of Gottingen. From that time on his labors were continuous for nearly half a century. During the next decade he was engaged with Gauss on the magnetic constants of the earth, and in 1840, as the result, the atlas of the earth's magnetism was published. A little later he took up the splendid work on the absolute measurement of electricity by which his name is best known. He had the largest share in the introduction of the absolute units of measurement, the electrodynamic, electrostatic and the electromagnetic systems, and he carried out the experimental work that introduced the last two. The invention of the electro dynamometer was perhaps as great a service as could have been rendered to exact science. During the last few years failing health had terminated his scientific labors, but he had no need for further fame.

Electrical Execution at Sing Sing

The four condemned murderers who have been awaiting execution at Sing Sing, James J. Slocum, Harris A. Smiler, Joseph Wood and Shibuya Jugiro, paid the last penalty of the law early on the morning of July 7. The most strenuous efforts were made to avert the execution of these men by electricity. Finally, however, after many appeals, all were resentenced to die during the week beginning at midnight of July 6. At about ten minutes of five on Tuesday morning Slocum paid the penalty of his crimes, and following him miler, Wood and Jugiro in the order named. In an hour and twenty-three minutes all was over. There was none of the bungling that characterized the first electrical execution—that of Kemmler, last August. It is reported that all the men died at the first shock of the current without a struggle, thus finally setting at rest all the wild statements that have been made by ex parte experts and maudlin sentimentalists. The apparatus used was virtually the same that was employed in the Kemmler execution (see The Electrical World, Aug. 16, 1890). The chair was a duplicate of that then used, and the dynamo was almost identical. The only important change made, to which perhaps the successful result is in the main to be attributed, was the arrangement of both contact electrodes flexibly, so that electrical action could not be disturbed by any move ment of the prisoner's body.

Experiments with Alternate Currents of Very High Frequency, and Their Application to Methods of Artificial Illumination.*

BY NIKOLA TESLA.

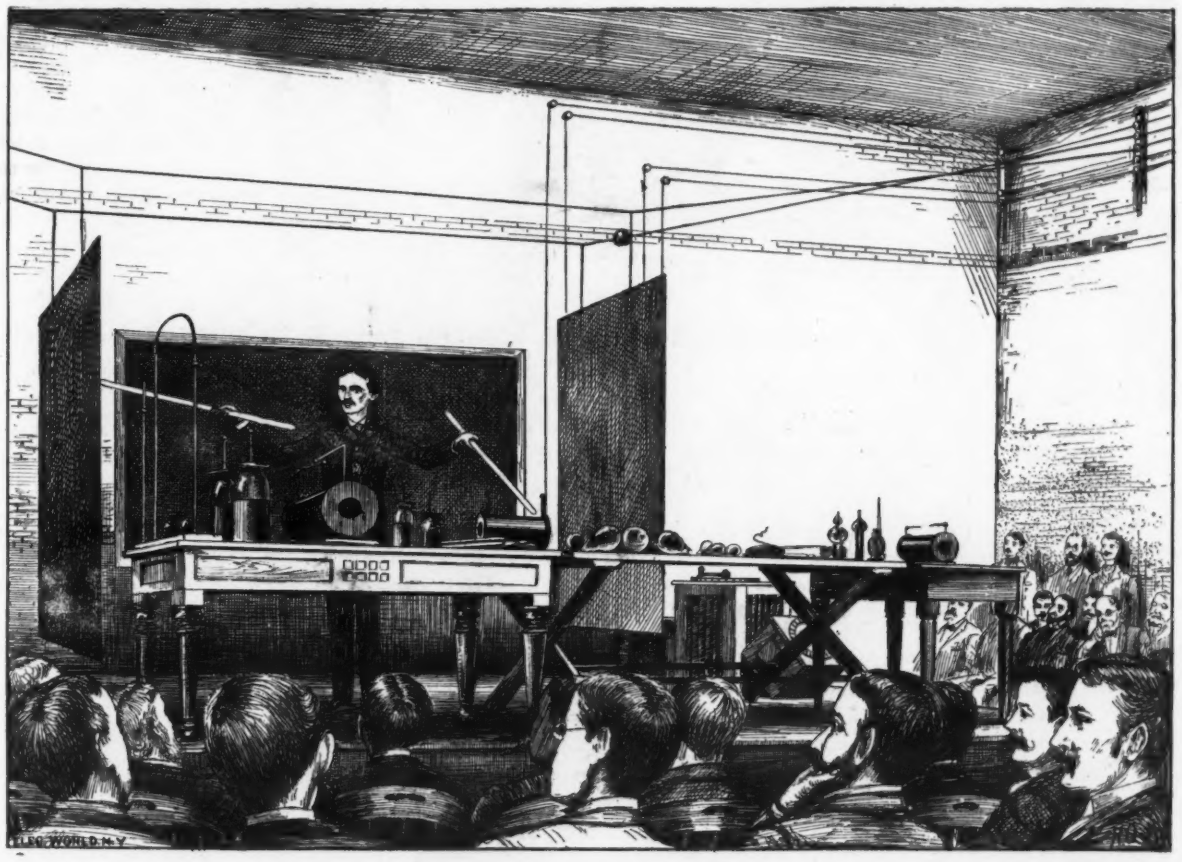
There is no subject more captivating, more worthy of study, than nature. To understand this great mechanism, to discover the forces which are active, and the laws which govern them, is the highest aim of the intellect of man.

Nature has stored up in the universe infinite energy. The eternal recipient and transmitter of this infinite energy is the ether. The recognition of the existence of ether, and of the functions it performs, is one of the most important results of modern scientific research. The mere abandoning of the idea of action at a distance, the assumption of a medium pervading all space and connecting all gross matter, has freed the minds of thinkers of an ever-present doubt, and, by opening a new horizon—new and unforeseen possibilities—has given fresh interest to phenomena with which we are familiar of old. It has been a great step toward the understanding of the forces of nature and their multifold manifestations to our senses. It has been for the enlightened student of physics what the understanding of the mechanism of the firearm or of the steam engine was for the barbarian. Phenomena upon which we used to look as wonders baffling explanation we now see in a different light. The spark of an induction coil, the glow of an incandescent lamp, the manifestations of the mechanical forces of currents and magnets are no longer beyond our grasp; instead of the incomprehensible, as before, their observation suggests now in our minds a simple mechanism, and although as to its precise nature all is still conjecture, yet we know that the truth cannot be much longer hidden, and instinctively we feel that the understanding is dawning upon us. We still admire these beautiful phenomena, these strange forces, but we are helpless no longer; we can in a certain measure explain them, account for them, and we are hopeful of finally succeeding in unraveling the mystery which surrounds them.

In how far we can understand the world around us is the ultimate thought of every student of nature. The coarseness of our senses prevents us from recognizing the ulterior construction of matter, and astronomy, this grandest and most positive of natural sciences, can only teach us something that happens, as it were, in our immediate neighborhood; of the remoter portions of the boundless universe, with its numberless stars and suns, we know nothing. But far beyond the limit of perception of our senses the spirit still can guide us, and so we may hope that even these unknown worlds—infinitely small and great—may in a measure become known to us. Still, even if this knowlege should reach us, the searching mind will find a barrier, perhaps forever unsurpassable, to the *true* recognition of that which *seems* to be, the mere *appearance* of which is the only and slender basis of all our philosophy.

Of all the forms of nature's immeasurable, all-pervading energy, which, ever and ever changing and moving, like a soul animates the inert universe, those of electricity and magnetism are perhaps the most fascinating. The effects of gravitation of heat and light we observe daily, and soon we get accustomed to them, and soon they lose for us the character of the marvelous and wonderful; but electricity and magnetism, with their singular relationship, with their seeming dual character unique among the forces in nature, with their phenomena of attractions, repulsions and rotations, strange manifestations of mysterious agents, stimulate and excite the mind to thought and research. What is electricity, and what is magnetism? These questions have been asked again and again. The most able intellects have ceaselessly wrestled with the problem; still the question has not as yet been fully answered. But while we cannot even to-day state what these singular forces are, yet we have made good headway toward the solution of the problem. We are now confident that electric and magnetic phenomena are attributable to ether, and we are perhaps justified in saying that the effects of static electricity are effects of ether under strain and those of dynamic electricity and electro-magnetism effects of ether in motion. But this still leaves the question, as to what electricity and magnetism are, unanswered.

First, we naturally inquire, What is electricity, and is there such a thing as electricity? In interpreting electric phenomena we may speak of electricity or of an electric condition, state or effect. If we speak of electric effects, we must distinguish two such effects opposite in character and neutralizing each other, as observation shows that two such opposite effects exist. This is unavoidable, for in a medium of the properties of ether we cannot possibly exert a strain or produce a displacement or motion of any kind without causing in the surrounding medium an equivalent and opposite effect. But if we speak of electricity, meaning a *thing*, we must, I think, abandon the idea of two electricities, as the existence of two such things is highly improbable. For how can we imagine that there should be two things, equivalent in amount, alike in their properties, but of opposite character, both clinging to matter, both attracting and completely neutralizing each other? Such an assumption, though suggested by many phenomena, though most convenient for explaining them, has little to commend it. If there *is* such a thing as electricity, there can be only *one* such thing, and excess and want of that one thing possibly, but more probably its condition determines the positive and negative character. The old theory of Franklin, though falling short in some respects, is, from a certain point of view, after all, the most plausible one. Still, in spite of this, the theory of the two electricities is generally accepted, as it apparently explains electric phenomena in a more satisfactory manner. But a theory which explains better the facts is not necessarily true. Ingenious minds will invent theories to suit observation, and almost every independent thinker has his own views on the subject.



MR. NIKOLA TESLA'S LECTURE BEFORE THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

It is not with the object of advancing an opinion, but with the desire of acquainting you better with some of the results which I will describe, to show you the reasoning I have followed, the departures I have made, that I venture to express in a few words the views and convictions which have led me to these results.

I adhere to the idea that there is a thing which we have been in the habit of calling electricity. The question is, What is that thing? or, What, of all things the existence of which we know, have we the best reason to call electricity? We know that it acts like an incompressible fluid; that there must be a constant quantity of it in nature; that it can be neither produced nor destroyed; and, what is more important, the electro-magnetic theory of light and all facts observed teach us that electric and ether phenomena are identical. The idea at once suggests itself, therefore, that electricity might be called ether. In fact, this view has in a certain sense been advanced by Dr. Lodge. His interesting work has been read by every one and many have been convinced by his arguments. His great ability and the interesting nature of the subject keep the reader spellbound; but when the impressions fade one realizes that he has to deal only with ingenious explanations. I must confess that I cannot believe in two electricities, much less in a doubly constituted ether. The puzzling behavior of the ether as a solid to waves of light and heat, and as a fluid to the motion of bodies through it, is certainly explained in the most natural and satisfactory manner by assuming it to be in motion, as Sir William Thomson has suggested; but regardless of this, there is nothing which would enable us to conclude with certainty that, while a fluid is not capable of transmitting transverse vibrations of a few hundred or thousand per second, it might not be capable of transmitting such vibrations when they range into hundreds of million millions per second. Nor can any one prove that there are transverse ether waves emitted from an alternate current machine, giving a small number of alternations per second; to such slow disturbances the ether, if at rest, may behave as a true fluid.

Returning to the subject, and bearing in mind that the existence of two electricities is, to say the least, highly improbable, we must remember that we have no evidence of electricity, nor can we hope to get it, unless gross matter is present. Electricity, therefore, cannot be called ether in the broad sense of the term; but nothing would seem to stand in the way of calling electricity ether associated with matter, or bound ether; or, in other words, that the so-called static charge of the molecule is ether associated in some way with the molecule. Looking at it in that light, we would be justified in saying that electricity is concerned in all molecular actions.

Now, precisely what the ether surrounding the molecules is, wherein it differs from ether in general, can only be conjectured. It cannot differ in density, ether being incompressible; it must, therefore, be under some strain or in motion, and the latter is the most probable. To understand its functions, it would be necessary to have an exact idea of the physical construction of matter, of which, of course, we can only form a mental picture.

But of all the views on nature, the one which assumes one matter and one force, and a perfect uniformity throughout, is the most scientific and most likely to be true. An infinitesimal world, with the molecules and their atoms spinning and moving in orbits, in much the same manner as celestial bodies, carrying with them and probably spinning with them ether, or, in other words, carrying with them static charges, seems to my mind the most probable view, and one which, in a plausible manner, accounts for most of the phenomena observed. The spinning of the molecules and their ether sets up ether tensions or electrostatic strains; the equalization of ether tensions sets up ether motions or electric currents, and the orbital movements produce the effects of electro and permanent magnetism.

About fifteen years ago Prof. Rowland demonstrated a most interesting and important fact, namely, that a static charge carried around produces the effects of an electric current. Leaving out of consideration the precise nature of the mechanism which produces the attraction and repulsion of currents, and conceiving the electrostatically charged molecules in motion, this experimental fact gives us a fair idea of magnetism. We can conceive lines or tubes of force which physically exist, being formed of rows of directed moving molecules; we can see that these lines must be closed; that they must tend to shorten and expand, etc. It likewise explains in a reasonable way the most puzzling phenomenon of all, permanent magnetism, and, in general, has all the beauties of the Ampère theory without possessing the vital defect of the same, namely, the assumption of molecular currents. Without enlarging further upon the subject, I would say that I look upon all electrostatic, current and magnetic phenomena as being due to electrostatic molecular forces.

The preceding remarks I have deemed necessary to a full understanding of the subject as it presents itself to my mind.

Of all these phenomena the most important to study are the current phenomena, on account of the already extensive and ever-growing use of currents for industrial purposes. It is now a century since the first practical source of current was produced, and ever since the phenomena which accompany the flow of currents have been diligently studied, and through the untiring efforts of scientific men the simple laws which govern them have been discovered. But these laws were found to hold good only when the currents are of a steady character. When the currents are rapidly varying in strength quite different phenomena, often unexpected, present themselves, and quite different laws hold good, which even now have not been determined as fully as is desirable, though through the work principally of English scientists enough knowledge has been gained on the subject to enable us to treat simple cases which now present themselves in daily practice.

The phenomena which are peculiar to the changing character of the currents are greatly exalted when the rate of change is increased, hence the study of these currents is considerably facilitated by the employment of

*A lecture delivered before the American Institute of Electrical Engineers, at Columbia College, May 20, 1891.

properly constructed apparatus. It was with this and other objects in view that I constructed alternate-current machines capable of giving more than two million reversals of current per minute, and to this circumstance it is principally due that I am able to bring to your attention some of the results thus far reached, which I hope will prove to be a step in advance on account of their direct bearing upon one of the most important problems, namely, the production of a practical and efficient source of light.

The study of such rapidly alternating currents is very interesting. Nearly every experiment discloses something new. Many results may, of course, be predicted, but many more are unforeseen. The experimenter makes many interesting observations. For instance, we take a piece of iron and hold it against a magnet. Starting from low alternations and running up higher and higher we feel the impulses succeed each other faster and faster, get weaker and weaker, and finally disappear. We then observe a continuous pull; the pull, of course, is not continuous; it only appears so to us; our sense of touch is imperfect.

We may next establish an arc between the electrodes and observe, as the alternations rise, that the note which accompanies alternating arcs gets shriller and shriller, gradually weakens, and finally ceases. The air vibrations, of course, continue, but they are too weak to be perceived; our sense of hearing fails us.

We observe the small physiological effects, the rapid heating of the iron cores and conductors, curious inductive effects, interesting condenser phenomena, and still more interesting light phenomena with a high-tension induction coil. All these experiments and observations would be of the greatest interest to the student, but their description would lead me too far from the principal subject. Partly for this reason, and partly on account of their vastly greater importance, I will confine myself to the description of the light effects produced by these currents.

In the experiments to this end a high-tension induction coil or equivalent apparatus for converting currents of comparatively low into currents of high tension is used.

If you will be sufficiently interested in the results I shall describe as to enter into an experimental study of this subject; if you will be convinced of the truth of the arguments I shall advance, your aim will be to produce high frequencies and high potentials; in other words, powerful electrostatic effects. You will then encounter many difficulties, which, if completely overcome, would allow us to produce truly wonderful results.

First will be met the difficulty of obtaining the required frequencies by means of mechanical apparatus, and, if they be obtained otherwise, obstacles of a different nature will present themselves. Next it will be found difficult to provide the requisite insulation without considerably increasing the size of the apparatus, for the potentials required are high, and owing to the rapidity of the alternations the insulation presents peculiar difficulties. So, for instance, when a gas is present the discharge may work through by the molecular bombardment of the gas and consequent heating, through as much as an inch of the best solid insulating material, such as glass, hard rubber, porcelain, sealing wax, etc.; in fact, through any known insulating substance. The chief requisite in the insulation of the apparatus is, therefore, the exclusion of any gaseous matter.

In general my experience tends to show that bodies which possess the highest specific inductive capacity, such as glass, afford a rather inferior insulation to others which, while they are good insulators, have a much smaller specific inductive capacity, such as oils, for instance, the dielectric losses being no doubt greater in the former. The difficulty of insulating, of course, only exists when the potentials are excessively high, for with potentials such as a few thousand volts there is no particular difficulty encountered in conveying currents from a machine giving, say, 20,000 alternations per second to quite a distance. This number of alternations, however, is by far too small for many purposes, though quite sufficient for some practical applications. This difficulty of insulating is fortunately not a vital drawback; it affects mostly the size of the apparatus, for, when excessively high potentials would be used, the light-giving devices would be located not far from the apparatus, and often they would be quite close to it. As the air bombardment of the insulated wire is dependent on condenser action, the loss may be reduced to a trifle by using excessively thin wires heavily insulated.

Another difficulty which will be encountered is the capacity and self-induction necessarily possessed by the coil. If the coil be large, that is, if it contains a great length of wire, it will be generally unsuited for excessively high frequencies; if it be small, it may be well adapted for such frequencies, but the potential might then not be as high as desired. A good insulator, and preferably one possessing a small specific inductive capacity, would afford a two-fold advantage. First, it would enable us to construct a very small coil capable of withstanding enormous differences of potential; and secondly, such a small coil, by reason of its smaller capacity of self-induction, would be capable of a quicker and more vigorous vibration. The problem, then, of constructing a coil or induction apparatus of any kind possessing the requisite qualities I regard as one of no small importance, and it has occupied me for considerable time.

The investigator who desires to repeat the experiments which I describe, with an alternate current machine, capable of supplying currents of the desired frequency, and an induction coil, will do well to take the primary coil out and mount the secondary in such a manner as to be able to look through the tube upon which the secondary is wound. He will then be able to observe the streams which pass from the primary to the insulating tube, and from their intensity he will know how far he can strain the coil. Without this precaution he is sure to injure the insulation. This arrangement permits, however, an easy exchange of the primaries, which is desirable in these experiments.

The selection of the type of machine best suited for the purpose must be left to the judgment of the experimenter. There are here illustrated three distinct types of machines, which, besides others, I have used in my experiments.

Fig. 1 represents the machine used in my experiments before this institute. The field magnet consists of a ring of wrought iron with 384 pole projections. The armature comprises a steel disc to which is fastened a thin, carefully welded rim of wrought iron. Upon the rim are wound several layers of fine, well annealed iron wire, which, when wound, is passed through shellac. The armature wires are wound around brass pins, wrapped with silk thread. The diameter of the armature wire in this type of machine should not be more than one-sixth of the thickness of the pole projections, else the local action will be considerable.

Fig. 2 represents a larger machine of a different type. The field magnet of this machine consists of two like parts which either inclose an exciting coil or else are independently wound. Each part has 480 pole projections, the projections of one facing those of the other. The armature consists of a wheel of hard bronze carrying the conductors which revolve between the projections of the field magnet. To wind the armature conductors, I have found it most convenient to proceed in the following manner: I construct a ring of hard bronze of the required size. This ring and the rim of the wheel are provided with the proper number of pins and both fastened upon a plate. Tha

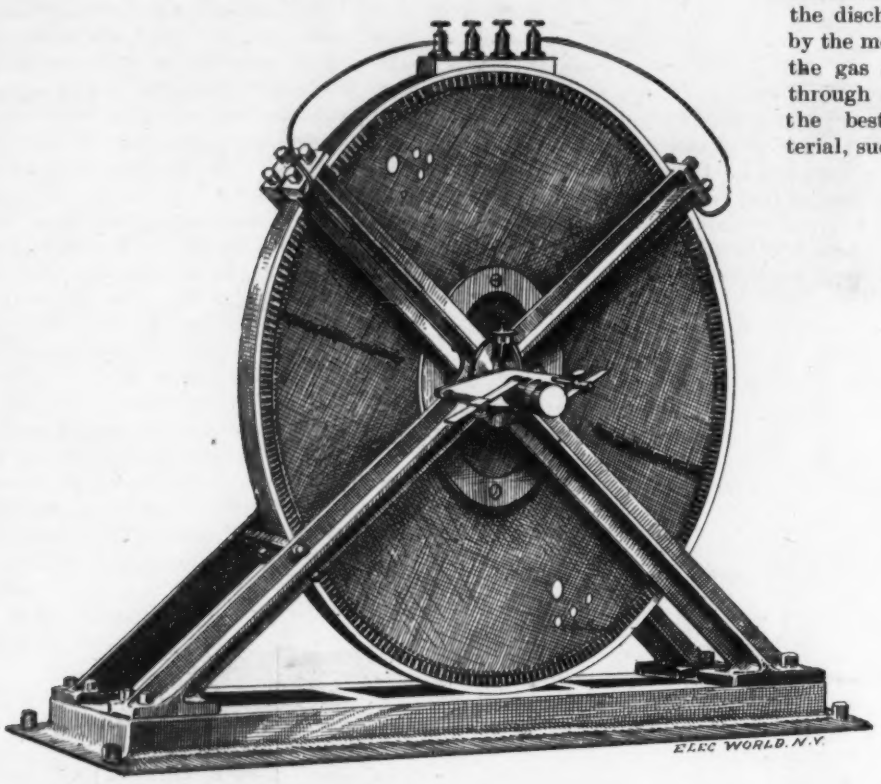


FIG. 1.—HIGH FREQUENCY ALTERNATING CURRENT MACHINE WITH DRUM ARMATURE.

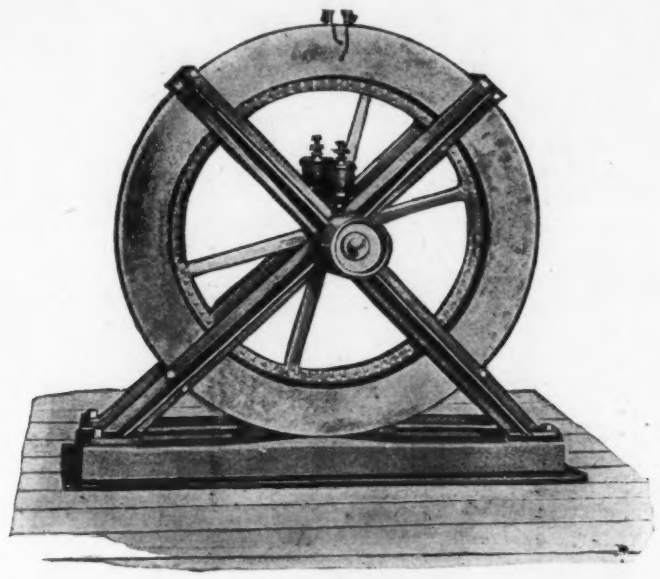


FIG. 2.—HIGH FREQUENCY ALTERNATOR WITH REVOLVING DISC ARMATURE.

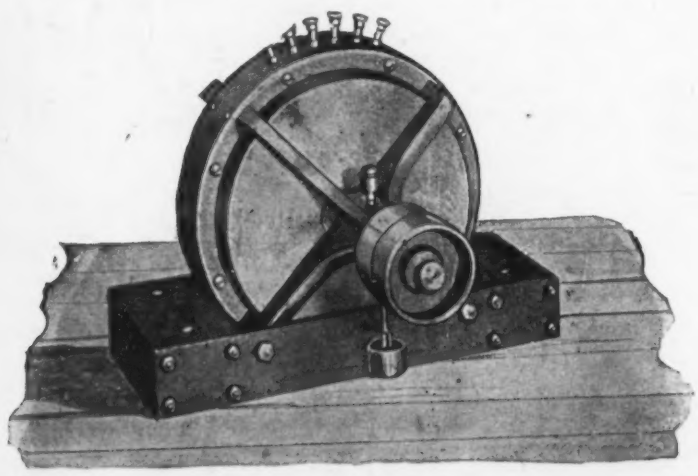


FIG. 3.—HIGH FREQUENCY ALTERNATOR WITH STATIONARY DISC ARMATURE AND STATIONARY EXCITING COIL.

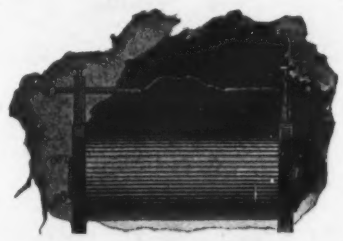


FIG. 4.—SENSITIVE THREAD DISCHARGE.

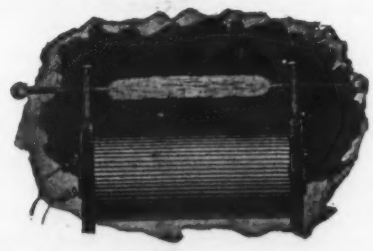


FIG. 5A.—FLAMING DISCHARGE.

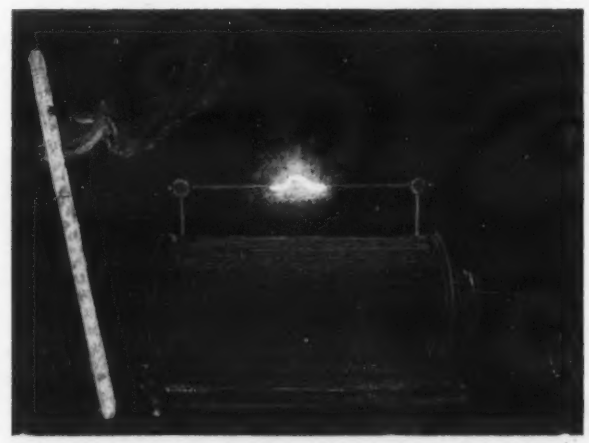


FIG. 5B.—FLAMING DISCHARGE FROM THE TERMINAL OF A HIGH TENSION COIL.

armature conductors being wound, the pins are cut and the ends of the conductors fastened by two off rings which screw to the bronze ring and the rim of the wheel respectively. The whole may then be taken off and forms a solid structure. The conductors in such a type of machine should consist of sheet copper, the thickness of which, of course, depends on the thickness of the pole projections; or else twisted thin wires should be employed.

Fig. 3 is a smaller machine, in many respects similar to the former, only here the armature conductors and the exciting coil are kept stationary, while only a block of wrought iron is revolved.

It would be uselessly lengthening this description were I to dwell more on the details of construction of these machines. I deem it well, however, to call the attention of the investigator to two things, the importance of which, though self-evident, he is nevertheless apt to underestimate: namely, to the local action in the conductors, which must be carefully avoided, and to the clearance, which must be small. I may add, that since it is desirable to use very high peripheral speeds, the armature should be of very large diameter in order to avoid impracticable belt speeds. Of the several types of these machines which have been constructed by me, I have found that the type illustrated in Fig. 1 caused me the least trouble in construction as well as in maintenance, and, on the whole, it has been a good experimental machine.

In operating an induction coil with very rapidly alternating currents, among the first luminous phenomena noticed are naturally those presented by the high-tension discharge. As the number of alternations per second is increased, or as—the number being high—the current through the primary is varied, the discharge gradually changes in appearance. It would be difficult to describe

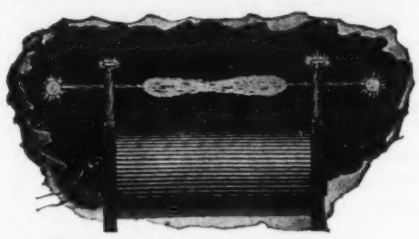


FIG. 6.—STREAMING DISCHARGE.

the minor changes which occur and the conditions which bring them about, but one may note five distinct forms of the discharge.

First, one may observe a weak, sensitive discharge in the form of a thin, feeble-colored thread (Fig. 4). It always occurs when, the number of alternations per second being high, the current through the primary is very small. In spite of the excessively small current, the rate of change is great and the difference of potential at the terminals of the secondary is therefore considerable, so that the arc is established at great distances; but the quantity of "electricity" set in motion is insignificant, barely sufficient to maintain a thin, thread-like arc. It is excessively sensitive and may be made so to such a degree that the mere act of breathing near the coil will affect it, and unless it is perfectly well protected from currents of air it wriggles around constantly. Nevertheless, it is in this form excessively persistent, and when the terminals are approached to, say, one-third of the striking distance, it can be blown out only with difficulty. This exceptional persistency, when short, is largely due to the arc being excessively thin; presenting, therefore, a very small surface to the blast. Its great sensitiveness, when very long, is probably due to the motion of the particles of dust suspended in the air.

When the current through the primary is increased the discharge gets broader and stronger, and the effect of the capacity of the coil becomes visible, until, finally, under proper conditions, a white flaming arc, Fig. 5, often as thick as one's finger and striking across the whole coil, is produced. It develops remarkable heat, and may be further characterized by the absence of the high note which accompanies the less powerful discharges. To take a shock from the coil under these conditions would not be advisable, although under different conditions, the potential being much higher, a shock from the coil may be taken with impunity. To produce this kind of discharge the number of alternations per second must not be too great for the coil used; and, generally speaking, certain relations between capacity, self-induction and frequency must be observed.

The importance of these elements in an alternate current circuit is now well known, and under ordinary conditions the general rules are applicable. But in an induction coil exceptional conditions prevail. First, the self-induction is of little importance before the arc is established, when it asserts itself, but perhaps never as prominently as in ordinary alternate current circuits, because capacity is distributed all along the coil, and by reason of the fact that the coil usually discharges through very great resistances; hence the currents are exceptionally small. Secondly, the capacity goes on increasing continually as the potential rises, in consequence of absorption which takes place to a considerable extent. Owing to this there exists no critical relationship between these quantities, and ordinary rules would not seem to be applicable. As the potential is increased either in consequence of the increased frequency or of the increased current through the primary, the amount of the energy stored becomes greater and greater and the capacity gains more and more in importance. Up to a certain point the capacity is beneficial, but after that it begins to be an enormous drawback. It follows from this that each coil gives the best result with a given frequency and primary current. A very large coil when operated with currents of very high frequency may not give as much as one-eighth inch spark. By adding capacity to the terminals the condition may be improved, but what the coil really wants is a lower frequency.

When the flaming discharge occurs the conditions are evidently such that the greatest current is made to flow through the circuit. These conditions may be attained by varying the frequency within wide limits, but the highest frequency at which the flaming arc can still be produced

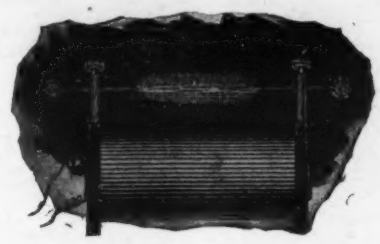


FIG. 7.—BRUSH AND SPRAY DISCHARGE.

determines, for a given primary current, the maximum striking distance of the coil. In the flaming discharge the effect of the capacity is not perceptible; the rate at which the energy is being stored then just equals the rate at which it can be disposed of through the circuit. This kind of discharge is the severest test for a coil; the break, when it occurs, is of the nature of that in an overcharged Leyden jar. To give a rough approximation, I would state that with an ordinary coil of, say, 10,000 ohms resistance, the most powerful arc would be produced with about 12,000 alternations per second.

When the frequency is increased beyond that rate the potential, of course, rises, but the striking distance may, nevertheless, diminish, paradoxical as it may seem. As the potential rises the coil attains more and more the properties of a static machine, until, finally, one may observe the beautiful phenomenon of the streaming discharge, Fig. 6, which may be produced across the whole length of the coil. At that stage streams begin to issue freely from all points and projections. These streams will also be seen to pass in abundance in the space between the primary and the insulating tube. When the potential is excessively high they will always appear, even if the frequency be low, and if even the primary be surrounded by as much as an inch of wax, hard rubber, glass or any other insulating substance. This limits greatly the output of the coil, but I will later show how I have been able to overcome to a considerable extent this disadvantage in the ordinary coil.

Besides the potential, the intensity of the streams depends on the frequency; but if the coil be very large they show themselves, no matter how low the frequencies used.

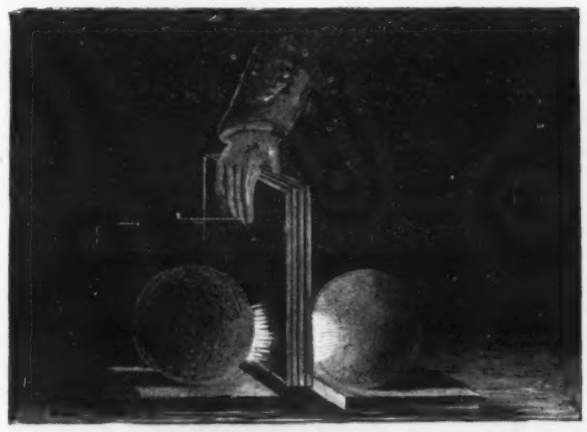


FIG. 9.—LUMINOUS DISCHARGE WITH INTERPOSED INSULATORS.

For instance, in a very large coil of a resistance of 67,000 ohms, constructed by me some time ago, they appear with as low as 100 alternations per second and less, the insulation of the secondary being three-quarter inch of ebonite. When very intense they produce a noise similar to that produced by the charging of a Holtz machine, but much more powerful, and they emit a strong smell of ozone. The lower the frequency, the more apt they are to suddenly injure the coil. With excessively high frequencies they may pass freely without producing any other effect than to heat the insulation slowly and uniformly.

The existence of these streams shows the importance of constructing an expensive coil so as to permit of one's seeing through the tube surrounding the primary, and the latter should be easily exchangeable, or else the space between the primary and secondary should be completely filled up with insulating material so as to exclude all air. The non-observance of this simple rule in the construction of the commercial coils is responsible for the destruction of many an expensive coil.

At the stage when the streaming discharge occurs, or with somewhat higher frequencies, one may, by approaching the terminals considerably and regulating properly the effect of capacity, produce a veritable spray of small silver-white sparks or a bunch of excessively thin silvery threads (Fig. 7) amidst a powerful brush—each spark or thread possibly corresponding to one alternation. This, when produced under proper conditions, is probably the most beautiful discharge, and when an air blast is directed against it it presents a singular appearance. The spray of sparks, when received through the body, causes some inconvenience, whereas, when the discharge simply streams nothing at all is likely to be felt if large conducting objects are held in the hands to protect them from receiving small burns.

If the frequency is still more increased, then the coil refuses to give any spark unless at comparatively small distances, and the fifth typical form of discharge may be observed (Fig. 8). The tendency to stream out and dissipate is then so great that when the brush is produced at one terminal no sparking occurs even if, as I have repeatedly tried, the hand, or any conducting object, is held within the stream; and, what is more singular, the luminous stream is not at all easily deflected by the approach of a conducting body.

At this stage the streams seemingly pass with the greatest freedom through considerable thicknesses of insulators, and it is particularly interesting to study their behavior. For this purpose it is convenient to connect to the terminals of the coil two metallic spheres which may be placed at any desired distance (Fig. 9). Spheres are preferable to plates, as the discharge can be better observed. By inserting dielectric bodies between the spheres beautiful discharge phenomena may be observed. If the spheres be quite close and a spark be playing between them, by interposing a thin plate of ebonite between the spheres the spark instantly ceases and the discharge spreads into an intensely luminous circle several inches in diameter, provided the spheres are sufficiently large. The passage of the stream heats, and, after a while, softens the rubber so much that two plates may be made to stick

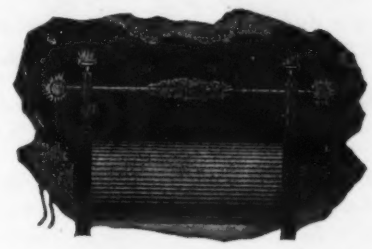


FIG. 8.—FIFTH TYPICAL FORM OF DISCHARGE.

together in this manner. If the spheres are so far apart that no spark occurs, even if they are far beyond the striking distance, by inserting a thick plate of glass the discharge is instantly induced to pass from the spheres to the glass in the form of luminous streams. It appears almost as though these streams pass *through* the dielectric. In reality this is not the case, as the streams are due to the molecules of the air which are violently agitated in the space between the oppositely charged surfaces of the spheres. When no dielectric other than air is present, the bombardment goes on, but is too weak to be visible; by inserting a dielectric the inductive effect is much increased and, besides, the projected air molecules find an obstacle, and the bombardment becomes so intense that the streams become luminous. If by any mechanical means we could effect such a violent agitation of the molecules we could produce the same phenomenon. A jet of air escaping through a small hole under enormous pressure and striking against an insulating substance, such as glass, may be luminous in the dark, and it might be possible to produce phosphorescence of the glass or other insulators in this manner.

The greater the specific inductive capacity of the interposed dielectric the more powerful the effect produced. Owing to this, the streams show themselves with excessively high potentials even if the glass be as much as one and one-half to two inches thick. But besides the heating due to bombardment, some heating goes on undoubtedly in the dielectric, being apparently greater in glass than in ebonite. I attribute this to the greater specific inductive capacity of the glass, in consequence of which, with the same potential difference, a greater amount of energy is taken up in it than in rubber. It is like connecting to a battery a copper and a brass wire of the same dimensions. The copper wire, though a more perfect conductor, would heat more by reason of its taking more current. Thus what is otherwise considered a virtue of the glass is here a defect. Glass usually gives way much quicker than ebonite; when it is heated to a certain degree the discharge suddenly breaks through at one point, assuming then the ordinary form of an arc.

The heating effect produced by molecular bombardment of the dielectric would, of course, diminish as the pressure of the air is increased, and at enormous pressures it would be negligible, unless the frequency should increase correspondingly.

It will be often observed in these experiments that when the spheres are beyond the striking distance the approach of a glass plate, for instance, may induce the spark to jump between the spheres. This occurs when the capacity of the spheres is somewhat below the critical value which gives the greatest difference of potential at the terminals of the coil. By approaching a dielectric the specific inductive capacity of the space between the spheres is increased, producing the same effect as if the capacity of the spheres were increased. The potential at the terminals may then

rise so high that the space is cracked. The experiment is best performed with dense glass or mica.

Another interesting observation is that a plate of insulating material, when the discharge is passing through it, is strongly attracted by either of the spheres; that is, by the nearer one, this being obviously due to the smaller mechanical effect of the bombardment on that side, and perhaps also to the greater electrification.

From the behavior of the dielectrics in these experiments we may conclude that the best insulator for these rapidly alternating currents would be the one possessing the smallest specific inductive capacity, and at the same time one capable of withstanding the greatest differences of potential; and thus two diametrically opposite ways of securing the required insulation are indicated, namely, to use either a perfect vacuum or a gas under great pressure; but the former would be preferable. Unfortunately, neither of these two ways is easily carried out in practice.

It is especially interesting to note the behavior of an excessively high vacuum in these experiments. If a test tube provided with external electrodes and exhausted to the

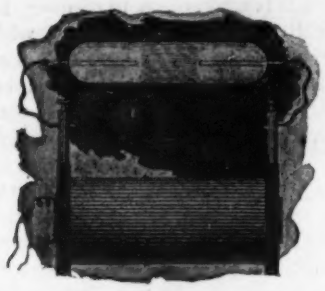


Fig. 10.—Discharge Through Highest Vacuum.

highest possible degree be connected to the terminals of the coil, Fig. 10, the electrodes of the tube are instantly brought to a high temperature, and the glass at each end of the tube is rendered intensely phosphorescent, but the middle appears comparatively dark, and for a while remains cool.

When the frequency is so high that the discharge shown in Fig. 8 is observed, considerable dissipation no doubt occurs in the coil. Nevertheless the coil may be worked for a long time, as the heating is gradual.

In spite of the fact that the difference of potential may be enormous, little is felt when the discharge is passed through the body, provided the hands are armed (see Fig. 18B). This is to some extent due to the higher frequency, but principally to the fact that less energy is available externally, when the difference of potential reaches an enormous value, owing to the circumstance that with the rise of potential the energy absorbed in the coil increases as the square of the potential. Up to a certain point the energy available externally increases with the rise of potential, then it begins to fall off rapidly. Thus, with the ordinary high tension induction coil, the curious paradox exists, that, while with a given current through the primary the shock might be fatal, with many times that current it might be perfectly

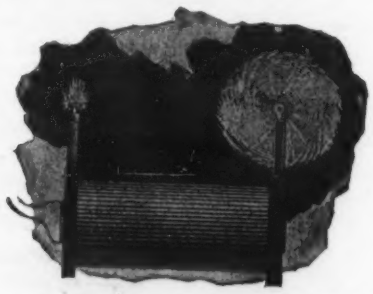


Fig. 11a.—Pinwheel Driven by a Powerful Brush.

harmless, even if the frequency be the same. With high frequencies and excessively high potentials when the terminals are not connected to bodies of some size, practically all the energy supplied to the primary is taken up by the coil. There is no breaking through, no local injury, but all the material, insulating and conducting, is uniformly heated.

To avoid misunderstanding in regard to the physiological effect of alternating currents of very high frequency, I think it necessary to state that while it is an undeniable fact that they are incomparably less dangerous than currents of low frequencies, yet it should not be thought that they are altogether harmless. What has just been said refers only to currents from an ordinary high-tension induction coil, which currents are necessarily very small; if received directly from a machine or from a secondary of low resistance they produce more or less powerful effects and may cause serious injury, especially when used in conjunction with condensers.

The streaming discharge of a high tension induction coil differs in many respects from that of a powerful static machine. In color it has neither the violet of the positive nor the brightness of the negative static discharge, but lies somewhere between, being, of course, alternatively positive and negative. But since the streaming is more powerful when the point of the terminal is electrified positively than when electrified negatively, it follows that the point of the brush is more like the positive, and the root more like the negative static discharge. In the dark, when the brush is very powerful, the root may appear almost white. The wind produced by the escaping streams, though it may be very strong—often, indeed, to such a degree that it may be felt quite a distance from the coil—is, nevertheless, considering the quantity of the discharge, smaller than that produced by the positive brush of a static machine, and it affects the flame much less powerfully. From the nature of the phenomenon we can conclude that the higher the frequency, the smaller must, of course, be the wind produced by the streams, and with sufficiently high frequen-

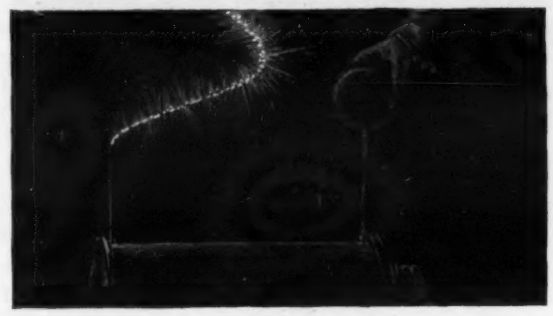


Fig. 12.—Luminous Streams Escaping from a Cotton-Covered Wire.

cies no wind at all would be produced at the ordinary atmospheric pressures. With frequencies obtainable by means of a machine the mechanical effect is sufficiently great to revolve, with considerable speed, large pin-wheels, which in the dark present a beautiful appearance, owing to the abundance of the streams (Figs. 11A and B.)

In general, most of the experiments usually performed with a static machine can be performed with an induction coil when operated with very rapidly alternating currents. The effects produced, however, are much more striking, being of incomparably greater power. When a small length of ordinary cotton-covered wire (Fig. 12) is attached

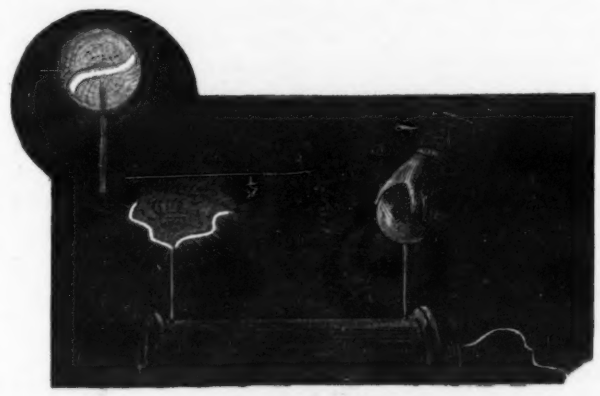


Fig. 11b.—Rotating Wire and Finwheel Effects.

to one terminal of the coil the streams issuing from all points of the wire may be so intense as to produce a considerable light effect. When the potentials and frequencies are very high, a wire insulated with gutta percha or rubber and attached to one of the terminals appears to be covered with a luminous film. A very thin bare wire when attached to a terminal emits powerful streams and vibrates continually to and fro or spins in a circle, producing a singular effect (Fig. 13). Some of these experiments have been described by me in The Electrical World of Feb. 21, 1891.

Another peculiarity of the rapidly alternating discharge

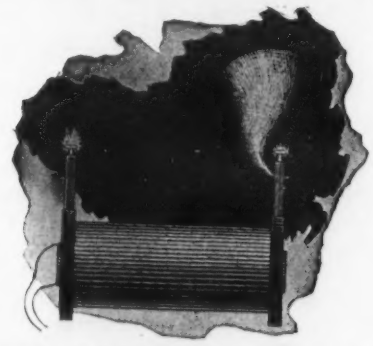


Fig. 13.—Aspect Presented by a very Thin Wire Attached to a Terminal of the Coil.

of the induction coil is its radically different behavior with respect to points and rounded surfaces.

If a thick wire, provided with a ball at one end and with a point at the other, be attached to the positive terminal of a static machine, practically all the charge will be lost through the point, on account of the enormously greater tension, dependent on the radius of curvature. But if such a wire is attached to one of the terminals of the induction coil it will be observed that with very high frequencies streams issue from the ball almost as copiously as from the point (Fig. 14).

It is hardly conceivable that we could produce such a condition to an equal degree in a static machine, for the simple reason that the tension increases as the square of the density, which in turn is proportional to the radius of curvature; hence, with a steady potential an enormous charge would be required to make streams issue from a polished ball while it is connected with a point. But with an induction coil, the discharge of which alternates with great rapidity, it is different. Here we have to deal with two distinct tendencies: First, there is the tendency to escape which exists in a condition of rest, and which depends on the radius of curvature; second, there is the tendency to dissipate into the surrounding air by condenser action, which depends on the surface. When one of these tendencies is at a maximum, the other is at a minimum. At the point the luminous stream is principally due to the air molecules coming bodily in contact with the point; they are attracted and repelled, charged and discharged, and, their atomic charges being thus disturbed, vibrate and emit light waves. At the ball, on the contrary, there is no doubt that the effect is to a great extent produced inductively, the air molecules not *necessarily* coming in contact with the ball, though they undoubtedly do so. To convince ourselves of this, we only need to exalt the condenser action, for instance, by enveloping the ball at some distance by a better conductor than the surrounding medium, the con-

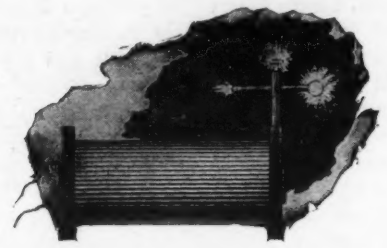


Fig. 14.—Effect of Ball and Point.

ductor being, of course, insulated; or else by surrounding it with a better dielectric and approaching an insulated conductor; in both cases the streams will break forth more copiously. Also, the larger the ball with a given frequency, or the higher the frequency, the more will the ball have the advantage over the point. But since a certain intensity of action is required to render the streams visible, it is obvious that in the experiment described the ball should not be taken too large.

In consequence of this twofold tendency it is possible to produce by means of points effects identical to those produced by capacity. Thus, for instance, by attaching to one terminal of the coil a small length of coiled wire, presenting many points and offering great facility to escape, the potential of the coil may be raised to the same value as by attaching to the terminal a polished ball of a surface many times greater than that of the wire.

An interesting experiment showing the effect of the points may be performed in the following manner: Attach to one of the terminals of the coil a cotton-covered wire about two feet in length and adjust the conditions so that streams issue from the wire. In this experiment the primary coil should be preferably placed so that it extends only about half way into the secondary coil. Now touch

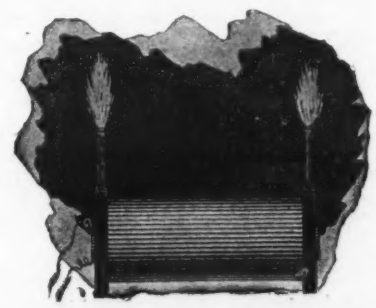


Fig. 15.—Aspect of Coil Under Powerful Brush Discharge.

the free terminal of the secondary with a conducting object held in the hand, or else connect it to an insulated body of some size. In this manner the potential on the wire may be enormously raised. The effect of this will be to either increase or to diminish the streams. If they increase, the wire is too short; if they diminish, it is too long. By adjusting the length of the wire a point is found where the touching of the other terminal does not at all affect the streams. In this case the rise of potential is exactly counteracted by the drop through the coil. It will be observed that small lengths of wire produce considerable difference in the magnitude and luminosity of the streams. The primary coil is placed sidewise for two reasons: First, to increase the potential at the wire, and, second, to increase the drop through the coil. The sensitiveness is thus augmented.

There is still another and far more striking peculiarity of the brush discharge produced by very rapidly alternating currents. To observe this it is best to replace the usual terminals of the coil by two metal columns insulated with a good thickness of ebonite. It is also well to close all fissures and cracks with wax so that the brushes cannot form anywhere except at the tops of the columns. If the conditions are carefully adjusted—which, of course, must be left to the skill of the experimenter—so that the potential rises to an enormous value, one may produce two powerful brushes several inches long, nearly white at their

roots, which in the dark bear a striking resemblance to two flames of a gas escaping under pressure (Fig. 15). But they do not only *resemble*, they *are* veritable flames, for they are hot. Certainly they are not as hot as a gas burner, *but they would be so if the frequency and the potential should be sufficiently high.* Produced with, say, twenty thousand alternations per second, the heat is easily perceptible even if the potential is not excessively high. The heat developed is, of course, due to the impact of the air molecules against the terminals and against each other. As, at the ordinary pressures, the mean free path is excessively small, it is possible that in spite of the enormous initial speed imparted to each molecule upon coming in contact with the terminal, its progress—by collision with other molecules—is retarded to such an extent that it does not get away far from the terminal, but may strike upon it many times in succession. The higher the frequency the less the molecule is able to get away, and this the more so as for a given effect the potential required is smaller; and a frequency is conceivable—perhaps even obtainable—at which practically the same molecules would strike the terminal. Under such conditions the exchange of the molecules would be very slow and the heat produced at, and very near, the terminal would be excessive. But if the frequency should go on increasing constantly, the heat produced would begin to diminish for obvious reasons. At the positive brush of a static machine the exchange of the molecules is very rapid, the stream is constantly of one direction, and there are fewer collisions; hence the heating effect must be very small. Anything that impairs the facility of exchange tends to increase the local heat produced. Thus, if a bulb be held over the terminal of the coil so as to inclose the brush, the air contained in the bulb is very quickly brought to a high temperature. If a glass tube be held over the brush so as to allow the draught to carry the brush upward, scorching hot air escapes at the top of the tube. Anything held within the brush is, of course, rapidly heated, and the possibility of using such heating effects for some purpose or other suggests itself.

FIG. 16.—INCANDESCENT WIRE OR FILAMENT SPINNING IN AN UNEXHAUSTED GLOBE.

When contemplating this singular phenomenon of the hot brush, we cannot help being convinced that a similar process must take place in the ordinary flame, and it seems strange that after all these centuries past of familiarity with the flame, now, in this era of electric lighting and heating, we are finally led to recognize that since time immemorial we have, after all, always had "electric light and heat" at our disposal. It is also of no little interest to contemplate, that we have a possible way of producing—by other than chemical means—a veritable flame, which would give light and heat without any material being consumed, without any chemical process taking place, and to accomplish this we only need to perfect methods of producing enormous frequencies and potentials. I have no doubt that if the potential could be made to alternate with sufficient rapidity and power, the brush formed at the end of a wire would lose its electrical characteristics and would become flamelike. The flame must be due to electrostatic molecular action.

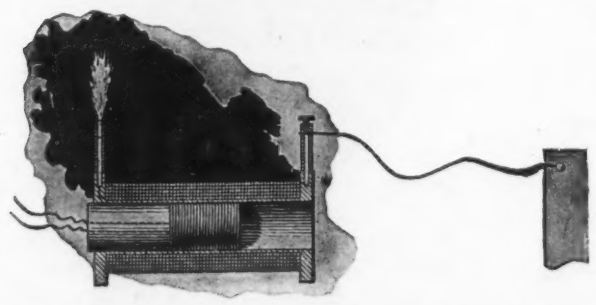


FIG. 17A.—COIL ARRANGED FOR POWERFUL BRUSH EFFECTS.

This phenomenon now explains in a manner which can hardly be doubted the frequent accidents occurring in storms. It is well known that objects are often set on fire without the lightning striking them. We shall presently see how this can happen. On a nail in a roof, for instance, or on a projection of any kind, more or less conducting or rendered so by dampness, a powerful brush may appear. If the lightning strikes somewhere in the neighborhood the enormous potential may be made to alternate or fluctuate perhaps many million times a second. The air molecules are violently attracted and repelled, and by their impact produce such a powerful heating effect that a fire is started. It is conceivable that a ship at sea may, in this manner, catch fire at many points at once. When we consider that even with the comparatively low frequencies obtained from a dynamo machine, and with potentials of no more than one or two hundred thousand volts, the heating effects are considerable, we may imagine how much more powerful they must be with frequencies and potentials many times greater; and the above explanation seems, to say the least, very probable. Similar explanations may have been suggested, but I am not aware that up to the present the heating effects of a brush produced by a rapidly alternating potential have been experimentally demonstrated, at least not to such a remarkable degree.

By preventing completely the exchange of the air molecules the local heating effect may be so exalted as to bring a body to incandescence. Thus, for instance, if a small button, or preferably a very thin wire or filament, be inclosed in an unexhausted globe and connected with the terminal of the coil, it may be rendered incandescent. The phenomenon is made much more interesting by the rapid spinning round in a circle of the top of the filament, thus presenting the appearance of a luminous funnel, Fig. 16, which widens when the potential is increased. When the potential is small the end of the filament may perform irregular motions, suddenly changing from one to the other, or it may describe an ellipse; but when the potential is verry high it always spins in a circle: and so does generally a thin, straight wire attached freely to the terminal of the coil. These motions are, of course, due to the impact of the molecules and the irregularity in the distribution of the potential, owing to the roughness and dissymmetry of the wire or filament. With a perfectly symmetrical and polished wire such motions would probably not occur. That the motion is not likely to be due to other causes is evident from the fact that it is not of a definite direction, and that in a very highly exhausted globe it ceases altogether. The possibility of bringing a body to incandescence in an unexhausted globe, or even when not at all inclosed, would seem to afford a possible way of obtaining lighting effects, which by perfecting methods of producing rapidly alternating potentials might be rendered available for useful purposes.

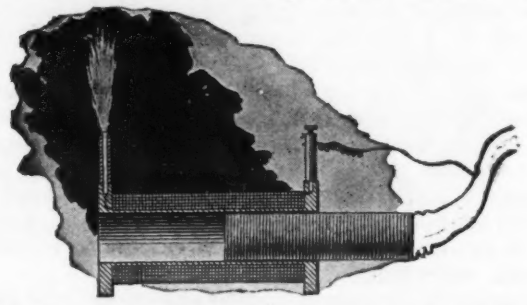


FIG. 17B.—COIL ARRANGED FOR POWERFUL BRUSH EFFECTS.—ST. ELMO'S HOT FIRE.

In employing a commercial coil, the production of very powerful brush effects is attended with considerable difficulties, for when these high frequencies and enormous potentials are used, the best insulation is apt to give way. Usually the coil is insulated well enough to stand the strain from convolution to convolution, since two double silk-covered paraffined wires will withstand a pressure of several volts; the difficulty lies principally in preventing the breaking through from the secondary to the primary, which is greatly facilitated by the streams issuing from the latter. In the coil, of course, the strain is greatest from section to section, but usually in a larger coil there are so many sections that the danger of a sudden giving way is not very great. No difficulty will generally be encountered in that direction, and besides the liability of injuring the coil internally is very much reduced by the fact that the effect most likely to be produced is simply a gradual heating, which, when far enough advanced, could not fail to be observed. The principal necessity is then to prevent the streams between the primary and the tube, not only on account of the heating and possible injury, but also because the streams may diminish very considerably the potential difference available at the terminals. A few hints as to how this may be accomplished will probably be found useful in most of these experiments with the ordinary induction coil.

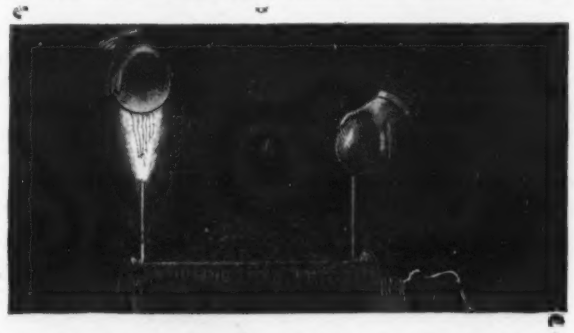


FIG. 18B.—TAKING A SHOCK OF A QUARTER OF A MILLION VOLTS.

One of the ways is to wind a short primary, Fig. 17 *A*, so that the difference of potential is not at that length great enough to cause the breaking forth of the streams through the insulating tube. The length of the primary should be determined by experiment. Both the ends of the coil should be brought out on one end through a plug of insulating material fitting in the tube as illustrated. In such a disposition one terminal of the secondary is attached to a body the surface of which is determined with the greatest care so as to produce the greatest rise in the potential. At the other terminal a powerful brush appears, which may be experimented upon.

The above plan necessitates the employment of a primary of a comparatively small size, and it is apt to heat when powerful effects are desirable for a certain length of time.

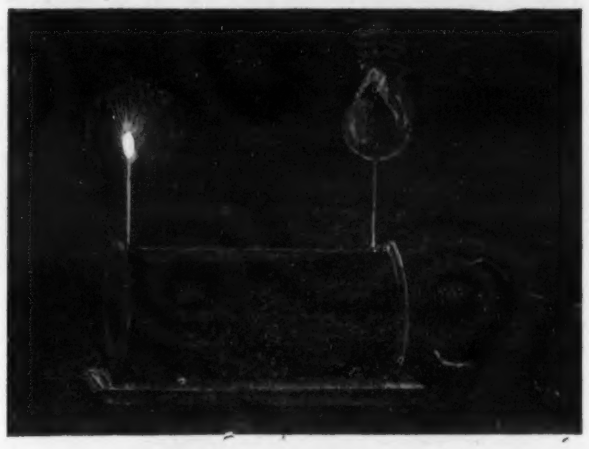


FIG. 17C.—COIL ARRANGED FOR POWERFUL BRUSH EFFECTS.

In such a case it is better to employ a larger coil in Fig. 17 *B*, and introduce it from one side of the tube until the streams begin to appear. In this case the nearest terminal of the secondary may be connected to the primary or to the ground, which is practically the same thing, if the primary is connected directly to the machine. In the case of ground connections it is well to determine experimentally the frequency which is best suited under the conditions of the test. Another way of obviating the streams, more or less, is to make the primary in sections and supply it from separate well-insulated sources.

In many of these experiments, when powerful effects are wanted for a short time it is advantageous to use iron cores with the primaries. In such case a very large primary coil may be wound and placed side by side with the secondary, and, the nearest terminal of the latter being connected to the primary, a laminated iron core is introduced through the primary into the secondary as far as the streams will permit. Under these conditions an excessively powerful brush, several inches long, which may be appropriately called "St. Elmo's hot fire," may be caused to appear at the other terminal of the secondary, producing striking effects. It is a most powerful ozonizer, so powerful, indeed, that only a few minutes are sufficient to fill the whole room with the smell of ozone, and it undoubtedly possesses the quality of exciting chemical affinities.

For the production of ozone alternating currents of very high frequency are eminently suited, not only on account of the advantages they offer in the way of conversion, but also because of the fact that the ozonizing action of a discharge is dependent on the frequency as well as on the potential, this being undoubtedly confirmed by observation.

In these experiments, if an iron core is used it should be carefully watched, as it is apt to get excessively hot in an incredibly short time. To give an idea of the rapidity of the heating, I will state that by passing a powerful current through a coil with many turns, the inserting within the same of a thin iron wire for no more than one second's time is sufficient to heat the wire to something like 100 degrees centigrade.

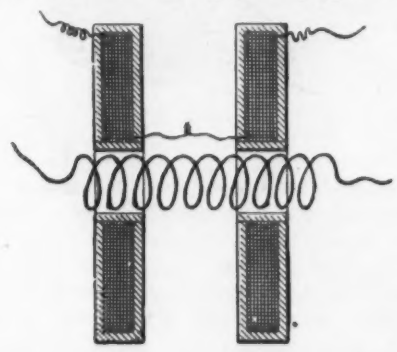


FIG. 18A.—COIL FOR PRODUCING VERY HIGH DIFFERENCE OF POTENTIAL.

But this rapid heating does not need to discourage us in the use of iron cores in connection with rapidly alternating currents. I have for a long time been convinced that in the industrial distribution by means of transformers some such plan as the following might be practicable. We may use a comparatively small iron core, subdivided, or perhaps not even subdivided. We may surround this core with a considerable thickness of material which is fireproof and conducts the heat poorly, and on top of that we may place the primary and secondary windings. By using either higher frequencies or greater magnetizing forces, we may by hysteresis and eddy currents heat the iron core so far as to bring it nearly to its maximum permeability, which, as Hopkinson has shown, may be as much as sixteen times greater than that at ordinary temperatures. If

the iron core were perfectly inclosed it would not be deteriorated by the heat, and if the inclosure of fireproof material would be sufficiently thick only a limited amount of energy could be radiated in spite of the high temperature. Transformers have been constructed by me on that plan, but for lack of time no thorough tests have as yet been made.

Another way of adapting the iron core to rapid alternations, or, generally speaking, reducing the frictional losses, is to produce by continuous magnetization a flow of something like 7,000 or 8,000 lines per square centimetre through the core and then work with weak magnetizing forces and preferably high frequencies around the point of greatest permeability. A higher efficiency of conversion and greater output are obtainable in this manner. I have also employed this principle in connection with machines in which there is no reversal of polarity. In these types of machines, as long as there are only a few

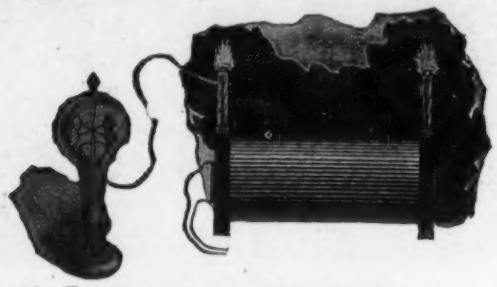


Fig. 19.—The Crookes Experiment on Open Circuit.

pole projections there is no great gain, as the maxima and minima of magnetization are far from the point of maximum permeability; but when the number of the pole projections is very great, the required rate of change may be obtained without the magnetization varying so far as to depart greatly from the point of maximum permeability, and the gain is considerable.

The above described arrangements refer only to the use of commercial coils as ordinarily constructed. If it is desired to construct a coil for the express purpose of performing with it such experiments as I have described, or, generally, rendering it capable of withstanding the greatest possible difference of potential, then a construction as indicated in Fig. 18A will be found of advantage. The coil in this case is formed of two independent parts which are wound oppositely, the connection between both being made near the primary. The potential in the middle being zero, there is not much tendency to jump to the primary and not much insulation is required. In some cases the middle point may, however, be connected to the primary or to the ground. In such a coil the places of greatest difference of potential are far apart and the coil is capable of withstanding an enormous strain. The two parts may be movable so as to allow a slight adjustment of the capacity effect.

As to the manner of insulating the coil, it will be found convenient to proceed in the following way: First the wire should be boiled in paraffine until the air is out; then the coil is wound by running the wire through melted paraffine merely for the purpose of fixing the wire. The coil is then taken off from the spool, immersed in a cylindrical vessel filled with pure melted wax and boiled for a long time until the bubbles cease to appear. The whole is then left to cool down thoroughly, and then the mass is taken out

Fig. 21.—Lamp with Two Filaments in Highest Vacuum with Leading-in Wires.

of the vessel and turned up in a lathe. A coil made in this manner and with care is capable of withstanding enormous potential differences.

It may be found convenient to immerse the coil in paraffine oil or some other kind of oil; it is a most effective way of insulating, principally on account of the perfect exclusion of air, but it may be found that after all a vessel filled with oil is not a very convenient thing to handle in a laboratory.

If an ordinary coil can be dismounted, the primary may be taken out of the tube and the latter plugged up on one end, filled with oil, and the primary reinserted. This affords an excellent insulation, and prevents the formation of the streams.

Of all the experiments which may be performed with rapidly alternating currents, the most interesting are those which concern the production of a practical illuminant. It cannot be denied that the present methods, though they were brilliant advances, are very wasteful. Some better methods must be invented, some more perfect apparatus devised. Modern research has opened new possibilities for the production of an efficient source of light, and the attention of all has been carried in the direction indicated by able pioneers. Many have been carried away by the enthusiasm and passion to discover, but in their zeal to reach results many have been misled. Starting with the idea of producing electromagnetic waves, they turned their attention perhaps too much to the study of electromagnetic effects and neglected the study of electrostatic phenomena. Naturally, nearly every investigator availed himself of an apparatus similar to that used in earlier experiments. But in those forms of apparatus, while the electro-magnetic inductive effects are enormous, the electrostatic effects are excessively small.

In the Hertz experiments, for instance, a high tension induction coil is short circuited by an arc, the resistance of which is very small; the smaller, the more capacity is attached to the terminals; and the difference of potential at these is enormously diminished. On the other hand, when the discharge is not passing between the terminals the static effects may be considerable, but only qualitatively so, not quantitatively, since their rise and fall is very sudden and since their frequency is small. In neither case, therefore, are powerful electrostatic effects perceivable. Similar conditions exist when, as in some interesting experiments of Dr. Lodge, Leyden jars are discharged disruptively. It has been thought—and I believe asserted—that in such cases most of the energy is radiated into space. In the light of the experiments which I have described above, it will not now be thought so. I feel safe in asserting that in such cases most of the energy is partly taken up and converted into heat in the arc of the discharge and in the conducting and insulating material of the jar, some energy being, of course, given off by electrification of the air, but the amount of the directly radiated energy is very small.

When a high tension induction coil, operated by currents alternating only 20,000 times a second, has its terminals closed through even a very small jar, practically all the energy passes through the dielectric of the jar, which is heated, and the electrostatic effects manifest themselves

Fig. 20.—Lamp with Single Block of Refactory Material, and Single Filament Lamp.

outwardly only to a very weak degree. Now the external circuit of a Leyden jar—that is, the arc and the connections of the coatings—may be looked upon as a circuit generating alternating currents of excessively high frequency and fairly high potential, which is closed through the coatings and the dielectric between them, and from the above it is evident that the external electrostatic effects must be very small, even if a recoil circuit be used. These conditions make it appear that with the apparatus usually at hand the observation of powerful electrostatic effects was impossible, and what experience has been gained in that direction is only due to the great ability of the investigators.

But powerful electrostatic effects are the *sine qua non* of light production on the lines indicated by theory. Electromagnetic effects are primarily unavailable, for the reason that to produce the required effects we would have to pass current impulses through a conductor which, long before the required frequency of the impulses could be reached, would cease to transmit them. On the other hand, electromagnetic waves many times longer than those of light and producible by sudden discharges of a condenser could not be utilized, it would seem, except we avail ourselves of their effect upon conductors as in the present methods, which are wasteful. We could not affect by means of such waves the static molecular or atomic charges of a gas, cause them to vibrate and to emit light. Long transverse waves apparently cannot produce such effects, since excessively small electromagnetic disturbances may pass readily through miles of air. Such dark waves, unless they are of the length of true light waves, cannot, it would seem, excite luminous radiation in a Geissler tube, and the luminous effects which are producible by induction in a tube devoid of electrodes I am inclined to consider as being of an electrostatic nature.

To produce such luminous effects straight electrostatic thrusts are required; these, whatever be their frequency, may disturb the molecular charges and produce light. Since current impulses of the required frequency cannot pass through a conductor of measurable dimensions, we must work with a gas, and then the production of powerful electrostatic effects becomes an imperative necessity.

It has occurred to me, however, that electrostatic effects are in many ways available for the production of light. For instance, we may place a body of some refractory material in a closed, and preferably more or less exhausted, globe, connect it to a source of high, rapidly alternating potential, causing the molecules of the gas to strike it many times a second at enormous speeds, and in this manner, with trillions of invisible hammers, pound it until it gets incandescent; or we may place a body in a very highly exhausted globe, in a non-striking vacuum, and by employing very high frequencies and potentials transfer sufficient energy from it to other bodies in the vicinity or in general to the surroundings, to maintain it at any degree of incandescence; or we may, by means of such rapidly alternating high potentials, disturb the ether carried by the molecules of a gas or their static charges and cause them to vibrate and to emit light.

But the electrostatic effects being dependent upon the potential and frequency, to produce the most powerful action it is desirable to increase both as far as practicable.

Fig. 22.—Lamp with Two Refractory Blocks in Highest Vacuum.

It may be possible to obtain quite fair results by keeping either of these factors small, provided the other is sufficiently great; but we are limited in both directions. My experience demonstrates that we cannot go below a certain frequency, for, first, the potential then becomes so great that it is dangerous; and, secondly, the light production is less efficient.

I have found that by using the ordinary low frequencies the physiological effect of the current required to maintain at a certain degree of brightness a tube four feet long provided at the ends with outside and inside condenser coatings, is so powerful that it might produce serious injury to those not accustomed to such shocks; whereas, with 20,000 alternations per second the tube may be maintained at the same degree of brightness without any effect being felt. This is due principally to the fact that a much smaller potential is required to produce the same light effect, and also to the higher efficiency in the light production. It is evident that the efficiency in such cases is the greater, the higher the frequency; for the quicker the process of charging and discharging the molecules, the less energy will be lost in the form of dark radiation. But, unfortunately, we cannot go beyond a certain frequency on account of the difficulty of producing and conveying the effects.

I have stated above that a body inclosed in an unexhausted bulb may be intensely heated by simply connecting it with a source of rapidly alternating potential. The heating in such a case is in all probability due mostly to the bombardment of the molecules of the gas contained in the bulb. When the bulb is exhausted the heating of the body

Fig. 23.—Lamp with Single Straight Filament and One Leading-in Wire.

is much more rapid, and there is no difficulty whatever in bringing a wire or filament to any degree of incandescence by simply connecting it to one terminal of a coil of the proper dimensions. Thus, if the well-known apparatus of Prof. Crookes, consisting of a bent platinum wire with vanes mounted over it (Fig. 19), be connected to one terminal of the coil—either one or both ends of the platinum wire being connected—the wire is rendered almost instantly incandescent, and the mica vanes are rotated as though a current from a battery were used. A thin carbon filament, or, preferably, a button of some refractory material (Fig. 20), even if it be a comparatively poor conductor, inclosed in an exhausted globe, may be rendered highly incandescent; and in this manner a simple lamp capable of giving any desired candle power is provided.

The success of lamps of this kind would depend largely on the selection of the light-giving bodies contained within the bulb. Since, under the conditions described, refractory bodies—which are very poor conductors and capable

of withstanding for a long time excessively high degrees of temperature—may be used, such illuminating devices may be rendered successful.

It might be thought at first that if the bulb containing the filament or button of refractory material be perfectly well exhausted—that is, as far as it can be done by the use of the best apparatus—the heating would be much less intense, and that in perfect vacuum it could not occur at all. This is not confirmed by my experience; quite the contrary; the better the vacuum the easier the bodies are brought to incandescence. This result is interesting for many reasons.

At the outset of this work the idea presented itself to me,

FIG. 29B.—LIGHTING UP AN EXHAUSTED TUBE.

whether two bodies of refractory material inclosed in a bulb exhausted to such a degree that the discharge of a large induction coil operated in the usual manner cannot pass through, could be rendered incandescent by mere condenser action. Obviously, to reach this result enormous potential differences and very high frequencies are required, as is evident from a simple calculation.

But such a lamp would possess a vast advantage over an ordinary incandescent lamp in regard to efficiency. It is well known that the efficiency of a lamp is to some extent a function of the degree of incandescence, and that could we but work a filament of many times higher degrees of incandescence the efficiency would be much greater. In an ordinary lamp this is impracticable on account of the destruction of the filament, and it has been determined by experience how far it is advisable to push the incandescence. It is impossible to tell how much higher efficiency could be obtained if the filament could withstand indefinitely, as the investigation to this end obviously cannot be carried beyond a certain stage; but there are reasons for believing that it would be very considerably higher. An improvement might be made in the ordinary lamp by employing a short and thick carbon; but then the leading-in wires would have to be thick, and, besides, there are many other considerations which render such a modification entirely impracticable. But in a lamp as above described the leading-in wires may be very small, the incandescent refractory material may be in the shape of blocks offering a very small radiating surface, so that less energy would be required to keep them at the desired incandescence; and in addition to this the refractory material need not be carbon, but may be manufactured from mixtures of oxides, for instance, with carbon or other material, or may be selected from bodies which are practically non-conductors and capable of withstanding enormous degrees of temperature.

All this would point to the possibility of obtaining a much higher efficiency with such a lamp than is obtainable in

FIG. 26A.

FIG. 26B.

LAMP WITH ONE FILAMENT, ONE INSIDE AND ONE OUTSIDE CONDENSER COATING.

ordinary lamps. In my experience it has been demonstrated that the blocks are brought to high degrees of incandescence with much lower potentials than those determined by calculation, and the blocks may be set at greater distances from each other. We may freely assume, and it is probable that the molecular bombardment is an important element in the heating, even if the globe be exhausted with the utmost care as I have done; for although the number of the molecules is, comparatively speaking, insignificant, yet on account of the mean free path being very great there are fewer collisions and the molecules may reach much higher speeds, so that the heating effect due to this cause may be considerable, as in the Crookes experiments with radiant matter.

But it is likewise possible that we have to deal here with an increased facility of losing the charge in very high vacuum, when the potential is rapidly alternating, in which case most of the heating would be directly due to the surging of the charges in the heated bodies; or else the observed fact may be largely attributable to the effect of the points which I have mentioned above, in consequence of which the blocks or filaments contained in the vacuum are equivalent to condensers of many times greater surface than that calculated from their geometrical dimensions. Scientific men still differ in opinion as to whether a charge should or should not be lost in a perfect vacuum, or, in other words, whether either is or is not a conductor. If the former were the case, then a thin filament inclosed in a perfectly exhausted globe and connected to a source of enormous, steady potential would be brought to incandescence.

Various forms of lamps on the above-described principle with the refractory bodies in the form of filaments, Fig. 21, or blocks, Fig. 22, have been constructed and operated by me, and investigations are being carried on in this line. There is no difficulty in reaching such high degrees of incandescence that ordinary carbon is to all appearance melted and volatilized. If the vacuum could be made absolutely perfect such a lamp, although inoperative with apparatus ordinarily used, would, if operated with currents of the required character, afford an illuminant which would never be destroyed and which would be far more efficient than an ordinary incandescent lamp. This perfection can, of course, never be reached and a very slow destruction

FIG. 25.—LAMP WITH TWO BLOCKS OR FILAMENTS AND A PAIR OF INDEPENDENT INSIDE AND OUTSIDE CONDENSER COATINGS.

FIG. 28.—LAMP WITH ONE FILAMENT, ONE INSIDE AND ONE OUTSIDE CONDENSER COATING, AND AUXILIARY COATING.

and gradual diminution of the size always occurs, as in incandescent lamps; but there is no possibility of a sudden and premature disabling which occurs in the latter by the breaking of the filament, especially when the incandescent bodies are in the shape of blocks.

With these rapidly alternating potentials there is, however, no necessity of inclosing two blocks in a globe, but a single block, as in Fig. 20, or filament, Fig. 23, may be used. The potential in this case must of course be higher, but it is easily obtainable, and besides it is not necessarily dangerous.

The facility with which the button or filament in such a lamp is brought to incandescence, other things being equal, depends on the size of the globe. If a perfect vacuum

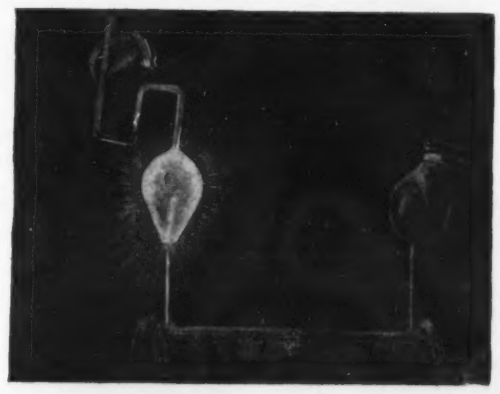


FIG. 24.—LAMPS WITH ONE LEADING-IN WIRE RENDERED INCANDESCENT.

could be obtained, the size of the globe would not be of importance, for then the heating would be wholly due to the surging of the charges and all the energy would be given off to the surroundings by radiation. But this can never occur in practice. There is always some gas left in the globe, and although the exhaustion may be carried to the highest degree still the space inside of the bulb must be considered as conducting when such high potentials are used, and I assume that in estimating the energy that may be given off from the filament to the surroundings we may consider the inside surface of the bulb as one coating of a condenser, the air and other objects surrounding the bulb forming the other coating. When the alternations are very low there is no doubt that a considerable portion of the energy is given off by the electrification of the surrounding air.

In order to study this subject better I carried on some experiments with excessively high potentials and low frequencies. I then observed that when the hand is approached to the bulb—the filament being connected with one terminal of the coil—a powerful vibration is felt, being due to the attraction and repulsion of the molecules of the air which are electrified by induction through the glass. In some cases when the action is very intense I have been able to hear a sound, which must be due to the same cause.

When the alternations are low, one is apt to get an excessively powerful shock from the bulb. In general, when one attaches bulbs or objects of some size to the terminals of the coil one should look out for the rise of potential, for it may happen that by merely connecting a bulb or plate to the terminal the potential may rise to many times its original value. When lamps are attached to the terminals, as illustrated in Fig. 24, then the capacity of the bulbs should be such as to give the maximum rise of potential under the existing conditions. In this manner one may obtain the required potential with fewer turns of wire.

The life of such lamps as described above depends, of course, largely on the degree of exhaustion, but to some extent also on the shape of the block of refractory material. Theoretically it would seem that a small sphere of carbon inclosed in a sphere of glass would not suffer deterioration from molecular bombardment, for the matter in the globe being radiant, the molecules would move in straight lines and would seldom strike the sphere obliquely. An interesting thought in connection with such a lamp is, that in it

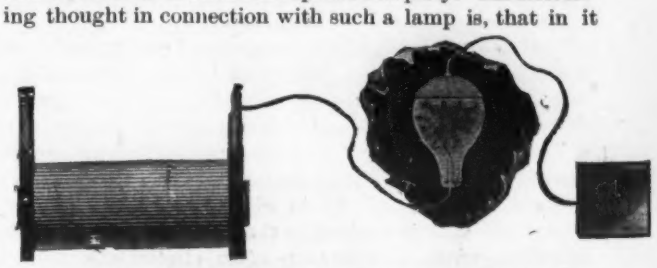


FIG. 29A.—INCREASING THE BRILLIANCY OF LAMP ON ONE WIRE.

"electricity" and electrical energy apparently must move in the same lines.

The use of alternating currents of very high frequency makes it possible to transfer by electrostatic or electromagnetic induction through the glass of a lamp sufficient energy to keep a filament at incandescence, and so do away with the leading-in wires. Such lamps have been proposed, but for want of proper apparatus they have not been successfully operated. Many forms of lamps on this principle with continuous and broken filaments have been constructed by me and experimented upon. When using a secondary inclosed within the lamp a condenser is advantageously combined with the secondary. When the transference is effected by electrostatic induction the potentials used are, of course, very high with frequencies obtainable from a machine. For instance, with a condenser surface of 40 centimetres square, which is not impracticably large, and with glass of good quality 1 millimetre thick, using currents alternating twenty thousand times a second, the potential required is approximately 9,000 volts. This may seem large, but since each lamp may be included in the secondary of a transformer of very small dimensions, it would not be inconvenient, and, moreover, it would not produce fatal injury. The transformers would all be preferably in series. The regulation would offer no difficulties, as with currents of such frequencies it is very easy to maintain a constant current.

In the accompanying engravings some of the types of lamps of this kind are shown. Fig. 25 is such a lamp with a broken filament, and Figs. 26 *A* and 26 *B* one with a single outside and inside coating and a single filament. I have also made lamps with two outside and inside coatings and a continuous loop connecting the latter. Such lamps have been operated by me with current impulses of the enormous frequencies obtainable by the disruptive discharge of condensers.

The disruptive discharge of a condenser is especially suited for operating such lamps—with no outward electrical connections—by means of electromagnetic induction, the electromagnetic inductive effects being excessively high; and I have been able to produce the desired incandescence with only a few short turns of wire. In-

FIG. 27.—LAMP WITH ONE FILAMENT AND LEADING-IN WIRE AND EXTERNAL CONDENSER COATING.

candescence may also be produced in this manner in a simple closed filament.

Leaving now out of consideration the practicability of such lamps, I would only say that they possess a beautiful and desirable feature, namely, that they can be rendered, at will, more or less brilliant simply by altering the relative position of the outside and inside condenser coatings or inducing and induced circuits.

When a lamp is lighted by connecting it to one terminal only of the source, this may be facilitated by providing the globe with an outside condenser coating, which serves at the same time as a reflector, and connecting this to an insulated body of some size. Lamps of this kind are illustrated in Fig. 27 and Fig. 28. Fig. 29A shows the plan of connections. The brilliancy of the lamp may, in this case, be regulated within wide limits by varying the size of the insulated metal plate to which the coating is connected.

It is likewise practicable to light with one leading wire lamps such as illustrated in Fig. 21 and Fig 22, by con-

necting one terminal of the lamp to one terminal of the source, and the other to an insulated body of the required size. In all cases the insulated body serves to give off the energy into the surrounding space, and is equivalent to a return wire. Obviously, in the two last-named cases, instead of connecting the wires to an insulated body, connections may be made to the ground.

The experiments which will prove most suggestive and of most interest to the investigator are probably those performed with exhausted tubes. As might be anticipated, a source of such rapidly alternating potentials is capable of exciting the tubes at a considerable distance and the light effects produced are remarkable.

During my investigations in this line I endeavored to excite tubes, devoid of any electrodes, by electromagnetic induction, making the tube the secondary of the induction device and passing through the primary the discharges of a Leyden jar. These tubes were made of many shapes, and I was able to obtain luminous effects which I then thought were due wholly to electromagnetic induction. But on carefully investigating the phenomena I found that the effects produced were more of an electrostatic nature. It may be attributed to this circumstance that this mode of exciting tubes is very wasteful; namely, the primary circuit being closed, the potential, and consequently the electrostatic inductive effect, is much diminished.

When an induction coil, operated as above described, is used, there is no doubt that the tubes are excited by electrostatic induction, and that electromagnetic induction has little, if anything, to do with the phenomena.

This is evident from many experiments. For instance, if a tube be taken in one hand, the observer being near the coil, it is brilliantly lighted, and remains so, no matter in what position it is held relatively to the observer's body. Were the action electromagnetic, the tube could not be lighted when the observer's body is interposed between it and the coil, or at least its luminosity should be considerably diminished. When the tube is held exactly over the centre of the coil—the latter being wound in sections and the primary placed symmetrically to the secondary—it may remain completely dark, whereas it is rendered intensely luminous by moving it slightly to the right or left from the centre of the coil. It does not light because in the middle both halves of the coil neutralize each other and the electric potential is zero. If the action were electromagnetic, the tube should light best in the plane through the centre of the coil, since the electromagnetic effect there should be a maximum. When an arc is established between the terminals, the tubes and lamps in the vicinity of the coil go out, but light up again when the arc is broken on account of the rise of potential. Yet the electromagnetic effect should be practically the same in both cases.

By placing a tube at some distance from the coil, and nearer to one terminal—preferably at a point on the axis of the coil—one may light it by touching the remote terminal with an insulated body of some size or with the hand, thereby raising the potential at that terminal nearer to the tube. If the tube is shifted nearer to the coil, so that it is lighted by the action of the nearer terminal, it may be made to go out by holding, on an insulated support, the

FIG. 30.—IDEAL METHOD OF LIGHTING A ROOM—TUBES DEVOID OF ANY ELECTRODES RENDERED BRILLIANT IN AN ALTERNATING ELECTROSTATIC FIELD.

end of a wire connected to the remote terminal in the vicinity of the nearer terminal, by this means counteracting the action of the latter upon the tube. These effects are evidently electrostatic. Likewise, when a tube is placed at considerable distance from the coil, the observer may, standing upon an insulated support, between the coil and tube, light the latter by approaching the hand to it; or he may even render it luminous by simply stepping between it and the coil. This would be impossible with electromagnetic induction, for the body of the observer would act as a screen.

When the coil is energized by excessively weak currents, the experimenter may, by touching one terminal of the coil with the tube, extinguish the latter, and may again light it by bringing it out of contact with the terminal and allowing a small arc to form. This is clearly due to the respective lowering and raising of the potential at that terminal. In the above experiment, when the tube is lighted through a small arc it may go out when the arc is broken, because the electrostatic inductive effect alone is too weak, though the potential may be much higher; but when the arc is established the electrification of the end of the tube is much greater and it consequently lights.

If a tube is lighted by holding it near to the coil, and in the hand which is remote, by grasping the tube anywhere with the other hand the part between the hands is rendered dark, and the singular effect of wiping out the light of the tube may be produced by passing the hand quickly along the tube and at the same time withdrawing it slightly from the coil, judging properly the distance so that the tube remains dark afterward.

If the primary coil is placed sidewise, as in Fig. 17 *B*, for instance, and an exhausted tube be introduced from the other side in the hollow space, the tube is lighted most intensely because of the increased condenser action, and in this position the striæ are most sharply defined. In all

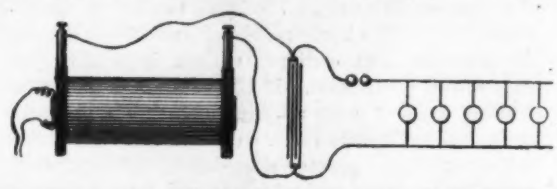


FIG. 31.—DIAGRAM OF CONNECTIONS FOR CONVERTING FROM HIGH TO LOW TENSION BY MEANS OF THE DISRUPTIVE DISCHARGE.

these experiments described and in many others the action is clearly electrostatic.

The effects of screening also indicate the electrostatic nature of the phenomena and show something of the nature of electrification through the air. For instance, if a tube be placed in the direction of the axis of the coil and an insulated metal plate be interposed, the tube will generally increase in brilliancy, or if it be too far from the coil to light, it may even be rendered luminous by interposing an insulated metal plate. The magnitude of the effects depends to some extent on the size of the plate. But if the metal plate be connected by a wire to the ground, its interposition will always make the tube go out, even if it be very near the coil. In general, the interposition of a body between the coil and tube increases or diminishes the brilliancy of the tube or its facility to light up, according to whether it increases or diminishes the electrification. When experimenting with an insulated plate the plate should not be taken too large, else it will generally produce a weakening effect by reason of its great facility for giving off energy to the surroundings.

If a tube be lighted at some distance from the coil and a plate of hard rubber or other insulating substance be interposed, the tube may be made to go out. The interposition of the dielectric in this case only slightly increases the inductive effect, but diminishes considerably the electrification through the air.

In all the cases, then, when we excite luminosity in exhausted tubes by means of such a coil, the effect is due to the rapidly alternating electrostatic potential; and, furthermore, it must be attributed to the harmonic alternation produced directly by the machine and not to any superimposed vibration which might be thought to exist. Such superimposed vibrations are impossible when we work with an alternate current machine. If a spring be gradually tightened and released it does not perform independent vibrations; for this a sudden release is necessary. So with the alternate currents from a dynamo machine; the medium is harmonically strained and released, this giving rise to only one kind of waves; a sudden contact or break, or a sudden giving way of the dielectric, as in the disruptive discharge of a Leyden jar, are essential for the production of superimposed waves.

In all the last described experiments tubes devoid of any electrodes may be used and there is no difficulty in producing by their means sufficient light to read by. The light effect is, however, considerably increased by the use of phosphorescent bodies such as yttria, uranium glass, etc. A difficulty will be found when the phosphorescent material is used, for with these powerful effects it is carried gradually away, and it is preferable to use material in the form of a solid.

Instead of depending on induction at a distance to light the tube, the same may be provided with an external—and, if desired, also with an internal—condenser coating, and may then be suspended anywhere in the room from a conductor connected to one terminal of the coil, and in this manner a soft illumination may be provided.

The ideal way of lighting a hall or room would, however, be to produce such a condition in it that an illuminating device could be moved and put anywhere, and that it is lighted no matter where it is put and without being electrically connected to anything. I have been able to produce such a condition by creating in the room a powerful, rapidly alternating electrostatic field. For this purpose I suspend a sheet of metal at a distance from the ceiling on insulating cords and connect it to one terminal of the induction coil, the other terminal being preferably connected to the ground. Or else I suspend two sheets as illustrated in Fig. 30, each sheet being connected with one of the terminals of the coil, and their size being carefully determined. An exhausted tube may then be carried in the hand anywhere between the sheets or placed any-

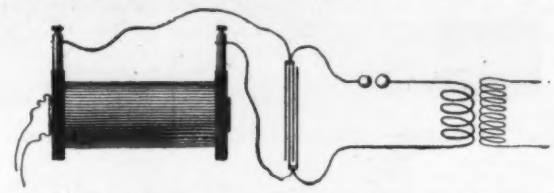


FIG. 32.—MANNER OF OPERATING AN INDUCTION COIL.

where, even a certain distance beyond them: it remains always luminous.

In such an electrostatic field interesting phenomena may be observed, especially if the alternations are kept low and the potentials excessively high. In addition to the luminous phenomena mentioned, one may observe that any insulated conductor gives sparks when the hand or another object is approached to it, and the sparks may often be powerful. When a large conducting object is fastened on an insulating support and the hand approached to it, a vibration, due to the rhythmical motion of the air molecules, is felt, and luminous streams may be perceived when the hand is held near a pointed projection. When a telephone receiver is made to touch with one or both of its terminals an insulated conductor of some size, the telephone emits a loud sound; it also emits a sound when a length of wire is attached to one or both terminals, and with very powerful fields a sound may be perceived even without any wire.

How far this principle is capable of practical application the future will tell. It might be thought that electrostatic effects are unsuited for such action at a distance. Electromagnetic inductive effects, if available for the production of light, might be thought better suited. It is true the electrostatic effects diminish nearly with the cube of the distance from the coil, whereas the electromagnetic inductive effects diminish simply with the distance. But when we establish an electrostatic field of force the condition is very different, for then instead of the differential effect of both the terminals we get their conjoint effect. Besides, I would call attention to the fact, that in an alternating electrostatic field, a conductor, such as an exhausted tube, for instance, tends to take up most of the energy, whereas in an electromagnetic alternating field the conductor tends to take up the least energy, the waves being reflected with but little loss. This is one reason why it is difficult to excite an exhausted tube at a distance by electromagnetic induction. I have wound coils of very large diameter and of many turns of wire and connected a Geissler tube to the ends of the coil with the object of exciting the tube at a distance; but even with the powerful inductive effects producible by Leyden-jar discharges the tube could not be excited unless at a very small distance, although some judgment was used as to the dimensions of the coil. I have also found that even the most powerful Leyden-jar discharges are capable of exciting only feeble luminous effects in a closed exhausted tube, and even these effects upon thorough examination I have been forced to consider of an electrostatic nature.

How, then, can we hope to produce the required effects at a distance by means of electromagnetic action, when even in the closest proximity to the source of disturbance, under the most advantageous conditions, we can excite but faint luminosity? It is true that when acting at a distance we have the resonance to help us out. We can connect an exhausted tube or whatever the illuminating device may be with an insulated system of the proper capacity, and so it may be possible to increase the effect qualitatively, and only qualitatively, for we would not get *more* energy through the device. So we may, by resonance effect, obtain the required electromotive force in an exhausted tube and excite faint luminous effects, but we cannot get enough energy to render the light practically available, and a simple calculation, based on experimental results, shows that even if all the energy which a tube would receive at a certain distance from the source would be wholly converted into light, it would hardly satisfy the practical requirements. Hence the necessity of directing by means of a conducting circuit the energy to the place of transformation. But in so doing we cannot very sensibly depart from present methods, and all we could do would be to improve the apparatus.

From these considerations it would seem that if this ideal way of lighting is to be rendered practicable it will be only by the use of electrostatic effects. In such a case the most powerful electrostatic inductive effects are needed: the apparatus employed must, therefore, be capable of producing high electrostatic potentials, changing in value with extreme rapidity. High frequencies are especially

wanted, for practical considerations make it desirable to keep down the potential. By the employment of machines, or, generally speaking, of any mechanical apparatus, but low frequencies can be reached; recourse must, therefore, be had to some other means. The discharge of a condenser affords us a means of obtaining frequencies by far higher than are obtainable mechanically, and I have accordingly employed condensers in the experiments to the above end.

When the terminals of a high tension induction coil, Fig. 31, are connected to a Leyden jar and the latter is discharging disruptively into a circuit, we may look upon the arc playing between the knobs as being a source of alternating, or, generally speaking, undulating currents, and then we have to deal with the familiar system of a generator of such currents, a circuit connected to it and a condenser bridging the circuit. The condenser in such case is a vertical transformer, and since the frequency is excessive, almost any ratio in the strength of the currents in both the branches may be obtained. In reality the analogy is not quite complete, for in the disruptive discharge we have most generally a fundamental instantaneous variation of comparatively low frequency and a superimposed harmonic vibration, and the laws governing the flow of currents are not the same for both.

In converting in this manner the ratio of conversion should not be too great, for the loss in the arc between the knobs increases with the square of the current, and if the jar be discharged through very thick and short conductors, with the view of obtaining a very rapid oscillation, a very considerable portion of the energy stored is lost. On the other hand, too small ratios are not practicable for many obvious reasons.

As the converted currents flow in a practically closed circuit the electrostatic effects are necessarily small, and I therefore convert them into currents or effects of the required character. I have effected such conversions in several ways. The preferred plan of connections is illustrated in Fig. 32. The manner of operating renders it easy to obtain by means of a small and inexpensive apparatus enormous differences of potential which have been usually obtained by means of large and expensive coils. For this it is only necessary to take an ordinary small coil, adjust to it a condenser and discharging circuit forming the primary of an auxiliary small coil, and convert upward. As the inductive effect of the primary currents is excessively great, the second coil need have comparatively but very few turns. By properly adjusting the elements remarkable results may be secured.

In endeavoring to obtain the required electrostatic effects in this manner, I have, as might be expected, encountered many difficulties which I have been gradually overcoming, but at present I am not prepared to dwell upon my experiences in this direction.

I believe that the disruptive discharge of a condenser will play an important part in the future, for it offers vast possibilities not only in the way of producing light in a more efficient manner and in the line indicated by theory, but also in many other respects.

For years the efforts of inventors have been directed towards obtaining electrical energy from heat by means of the thermopile. It might seem invidious to remark that but few know what is the real trouble with the thermo pile. It is not the inefficiency or small output—though these are great drawbacks—but the fact that the thermopile has its phylloxera, that is, that by constant use it is deteriorated, which has thus far prevented its introduction on an industrial scale. Now that all modern research seems to point with certainty to the use of electricity of excessively high tension, the question must present itself to many whether it is not possible to obtain in a practicable manner this form of energy from heat. We have been used to look upon an electrostatic machine as a plaything, and somehow we couple with it the idea of the inefficient and impractical. But now we must think differently, for we know that everywhere we have to deal with the same forces, and that it is a mere question of inventing proper methods or apparatus for rendering them available.

In the present systems of electrical distribution the employment of iron, with its wonderful magnetic properties, allows us to reduce considerably the size of the apparatus; but, in spite of this, it is still very cumbersome. The more we progress in the study of electric and magnetic phenomena, the more we become convinced that the present methods will be short-lived. For the production of light, at least, such heavy machinery would seem to be unnecessary. The energy required is very small, and if light can be obtained as efficiently as theoretically appears possible, the apparatus need have but a very small output. There being a strong probability that the illuminating methods of the future will involve the use of very high potentials, it seems very desirable to perfect a contrivance capable of converting the energy of heat into energy of the requisite form. Nothing to speak of has been done toward this end, for the thought that electricity of some 50,000 or 100,000 volts pressure or more, even if obtained, would be unavailable for practical purposes, has deterred inventors from working in this direction.

In Fig. 31 a plan of connections is shown for converting currents of high into currents of low tension by means of the disruptive discharge of a condenser. This plan has been used by me frequently for operating a few incandescent lamps required in the laboratory. Some difficulties have been encountered in the arc of the discharge, which I have been able to overcome to a great extent; besides this, and the adjustment necessary for the proper working, no other difficulties have been met with, and it was easy to operate ordinary lamps and even motors in this manner. The line being connected to the ground, all the wires could be handled with perfect impunity, no matter how high the potential at the terminals of the condenser. In these experiments a high tension induction coil, operated from a battery or from an alternate current machine, was employed to charge the condenser; but the induction coil might be replaced by an apparatus of a different kind, capable of giving electricity of such high tension. In this

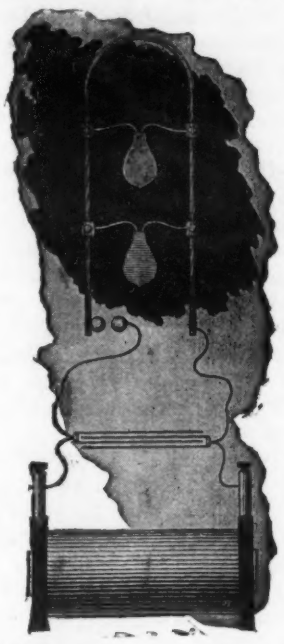


FIG. 33.—LAMP KEPT AT INCANDESCENCE ACROSS A THICK COPPER BAR—SHOWING NODES.

manner, direct or alternating currents may be converted, and in both cases the current impulses may be of any desired frequency. When the currents charging the condenser are of the same direction, and it is desired that the converted currents should also be of one direction, the resistance of the discharging circuit should, of course, be so chosen that there are no oscillations.

In operating devices on the above plan I have observed curious phenomena of impedance which are of interest. For instance, if a thick copper bar be bent as indicated in Fig. 33 and shunted by ordinary incandescent lamps, then by passing the discharge between the knobs the lamps may be brought to incandescence although they are short circuited. When a large induction coil is employed it is easy to obtain nodes on the bar which are rendered evident by the different degrees of brilliancy of the lamps, as shown roughly in Fig. 33. The nodes are never clearly pronounced, but there are simply maxima and minima of potential along the bar. This is probably due to the irregularity of the arc between the knobs. In general, when the above described plan of conversion from high to low tension is used, the behavior of the disruptive discharge may be closely studied. The nodes may also be investigated by

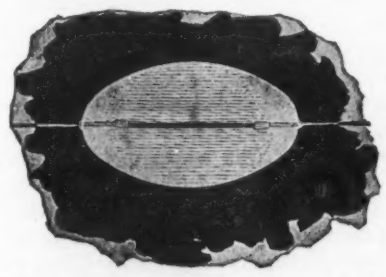


FIG. 34.—PHENOMENON OF IMPEDANCE IN AN INCADESCENT LAMP.

means of an ordinary Cardew voltmeter, which should be well insulated. Geissler tubes may also be lighted across the points of the bent bar; in this case of course it is better to employ smaller capacities. I have found it practicable to light up in this manner a lamp and even a Geissler tube shunted by a short, heavy block of metal, and this result seems at first very curious. In fact, the thicker the copper bar in Fig. 33 the better it is for the success of the experiments, as they appear more striking. When lamps with long, slender filaments are used it will be often noted that the filaments are from time to time violently vibrated, the vibration being smallest on the nodal points. This vibration seems to be due to an electrostatic action between the filament and the glass of the bulb.

In some of the above experiments it is preferable to use special lamps having a straight filament as shown in Fig. 34. When such a lamp is used a still more curious phenomenon than those described may be observed. The lamp may be placed across the copper bar and lighted, and by using somewhat larger capacities, or, in other words, smaller frequencies, or smaller impulsive impedances, the filament may be brought to any desired degree of incandescence. But when the impedance is increased, a point is reached when comparatively little current passes through the carbon and most of it through the rarefied gas; or perhaps it may be more correct to state that the current divides nearly evenly through both, in spite of the enormous difference in the resistance, and this would be true unless the gas and the filament behave differently. It is then noted that the whole bulb is brilliantly illuminated, and the ends of the leading-in wires become incandescent and often throw off sparks in consequence of the violent bombardment; but the carbon filament remains dark. This is illustrated in Fig. 34. Instead of the filament a single wire extending through the whole bulb may be used, and in this case the phenomenon would seem to be still more interesting.

From the above experiment it will be evident that when ordinary lamps are operated by the converted currents, those should be preferably taken in which the platinum wires are far apart, and the frequencies used should not be too great, else the discharge will occur at the ends of the filament or in the base of the lamp between the leading-in wires, and the lamp might then be damaged.

In presenting to you these results of my investigation on the subject under consideration I have paid only a passing notice to facts upon which I could have dwelt at length, and among many observations I have selected only those which I thought most likely to interest you. The field is wide and completely unexplored, and at every step a new truth is gleaned, a novel fact observed.

How far the results here borne out are capable of practical applications will be decided in the future. As regards the production of light some results already reached are encouraging and make me confident in asserting that the practical solution of the problem lies in the direction I have endeavored to indicate. Still, whatever may be the immediate outcome of these experiments I am hopeful that they will only prove a step to further development toward the ideal and final perfection. The possibilities which are opened by modern research are so vast that even the most reserved must feel sanguine of the future. Eminent scientists consider the problem of utilizing one kind of radiation without the others a rational one. In an apparatus designed for the production of light by conversion from any form of energy into that of light such a result can never be reached, for no matter what the process of producing the required vibrations, be it electrical, chemical or any other, it will not be possible to obtain the higher light vibrations without going through the lower heat vibrations. It is the problem of imparting to a body a certain velocity without passing through all lower velocities. But there is a possibility of obtaining energy, not only in the form of light, but motive power and energy of any other form in some more direct way from the medium. The time will be when this will be accomplished, and the time has come when one may utter such words before an enlightened audience without being considered a visionary. We are whirling through the endless space with an inconceivable speed; all around us everything is spinning, everything is moving, everywhere is energy. There *must* be some way of availing ourselves of this energy more directly. Then, with the light obtained from the medium, with the power derived from it, with every form of energy obtained without effort, from the store forever inexhaustible, humanity will advance with giant strides. The mere contemplation of these magnificent possibilities expands our minds, strengthens our hopes and fills our hearts with supreme delight.

A New Rotary Expansive Steam Engine.

Mr. A. F. G. Brown, of Ayrshire, has invented a new rotary engine, of which a description is given by the London *Electrical Engineer*. The engine consists of a cylinder of peculiar shape, ground to gauge, in which the piston revolves keyed to a central axle. The valves are arranged to cut off at the desired point and automatically close when exhaustion takes place. The engine has been made by Messrs. John Lang & Sons, of Johnstone, and tested by Prof. Jamieson, who has reported that on a series of trials of up to five consecutive hours the engine gave 29 i. h. p., and a mean of 20.78 brake h. p. at 574.5 revolutions, and an initial steam pressure in the cylinder of 80 pounds. The economy of steam, says the Glasgow *Herald*, is greater than any recorded results of any rotary steam engine, and quite equal to the very best performances of Willan's famous engines of the simple single cylinder, non-condensing type, for the gross weight of feed water used per indicated horse-power hour was only 27.2 pounds. This consumption would have been still less had it not been for the type of boiler used, the right angle bends in the steam pipes, and the neglect to have these pipes properly lagged and the cylinder jacketed, for 30 per cent of the weight of steam used passed into the cylinder as water held in suspension and from initial condensation. This is the first time, as far as we are able to learn, continues the *Herald*, that indicator diagrams have been taken from a rotary engine. Here, again, the improvements recently made by Mr. M'Innes, of Glasgow, on indicators allowed them to be obtained with a beautiful even expansion curve, and they enabled Prof. Jamieson to point out to the inventor wherein still further adaptations could be made for the benefit of the engine. The brake used at these tests was of the latest rope type, with Salter's spring balances for indicating the forward and backward stresses. It required neither oil nor black lead throughout the five hours run at full load, although bearing upon a specially large fly wheel.

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Chronological History of Electricity, Galvanism, Magnetism and the Telegraph, from B. C. 2637 to A. D. 1888.—Part I.*

BY P. F. MOTTELAY.

A. D. 1721.——Taylor (Brooke), L.L. D., F. R. S., an eminent English mathematician, past Secretary of the Royal Society, and one of the ablest geometers of his time—"the only one who, after the retreat of Newton, could safely enter the lists with the Bernoullis"—publishes his "Experiments on Magnetism" in *Phil. Trans.*, No. 368.

In order to arrive at a proper determination of the laws of magnetic force, Dr. Taylor—and also Whitson and Hauksbee—according to Sir David Brewster, considered the deviation of a compass needle from the meridian, produced by the action of a magnet at different distances; and the conclusion which they all drew from their experiments was that the magnetic force was proportional to the sines of half the arcs of deviation, or nearly in the inverse sesqui-duplicate ratio of the distance, or as the square roots of the fifth powers of the distances. Dr. Taylor had already come to the conclusion that the force was different in various magnets, and decreased quicker at great distances than at small ones, an experimental fact, as shown by Sir W. S. Harris, "Rud. Mag.," part III., p. 224.

In Dr. Thomas Thomson's "History of the Royal Society" we read (page 461) that Brooke Taylor, and after him Muschenbroek, attempted without success to determine by experiment the rate at which the magnetic attractions and repulsions vary. This rate was successfully investigated by the subsequent experiments of Lambert, Robison and Coulomb. The nature of magnetic curves was first satisfactorily explained by Lambert, Robison and Playfair. Brooke Taylor gave four poles to a wire by touching it at one end or at various parts, as indicated in *Phil. Trans.*, vol. 29, p. 294, and vol. 31, p. 204.

See Whewell. "Hist. of the Ind. Sciences," 1859, vol. I., pp. 359, 375; vol. II., p. 31.

A. D. 1722.——Graham (George), a celebrated optician and instrument maker in London, is the first to distinctly make known the diurnal and horary variations of the magnetic needle, traces of which had been merely recognized as facts by Gellibrand, in 1634, and by the Missionary Father Guy-Tachard at Louvo, in Siam, during 1682. He finds that its northern extremity begins to move westward at about seven or eight o'clock in the morning, and continues to deviate in that direction until about two o'clock in the afternoon, when it becomes stationary; it soon begins to return to the eastward and becomes again stationary during the night. Graham made nearly a thousand observations, between the 6th of February and the 12th of May, 1722, and found that the greatest westerly variation was 14° 45′, and the least 13° 50′; in general, however, it varied between 14° and 14° 35′, giving 35′ for the amount of the daily variation.

Graham's discovery, however, attracted but little attention until 1750, when the subject was ably taken up by Wargentin, Secretary to the Swedish Academy of Sciences. Between 1750 and 1759 Mr. John Canton made about 4,000 observations on the same subject, and was followed by the Dutch scientist Gerard van Swieten, the favorite pupil of Boerhaave, with like results.

As Dr. Lardner states ("Lectures on Science and Art," 1859, vol. II., p. 115), the same phenomenon has been observed more recently by Col. Beaufoy (at A. D. 1813), by Prof. Hausteen (at A. D. 1817) and by many others. He further states that Carsini, who observed the *diurnal* variation of the needle at Paris, found that neither the solar heat nor light influenced it, for it was the same in the deep caves constructed under the Observatory in Paris, where a sensibly constant temperature is preserved, and from which light is excluded, as at the surface. In northern regions these diurnal changes are greater and more irregular; while toward the line their amplitudes are gradually diminished until at length they disappear altogether.

It was Graham who first entertained the idea of measuring the magnetic intensity through the vibrations of the needle, a method subsequently used by Coulomb, and by many believed to have been invented by the latter. From the observations made by Humboldt and by Gay-Lussac in this manner, Biot has reduced the variation of intensity in different latitudes.

See "*Am. Journal Science*," vol. XXX., p. 225; Walker, "Magnetism," chap. II.; Fifth Dissertation of the 8th "Britannica," vol. I., p. 744; also *Phil. Trans.* 1724–1725, vol. XXXIII., p. 332, and pp. 96–107 ("An Account of Observations Made of the Horizontal Needle at London, 1722–1723, by Mr. George Graham"); *An. de chimie* for 1749, vol. XXV., p. 310.

A. D. 1726.——Wood (John), an English architect of considerable repute, is said to have shown that the electric current could be conveyed through wires a long distance.

See Jones, "Electrical Tel.," 1852, p. 7; Briggs, "Story of the Telegraph," 1858, p. 18.

A. D. 1729–1730.——Savery (Servington), English mechanician, succeeds in imparting magnetism to hard steel bar three-fourths of an inch square and 16 inches long, by fitting one bar with an armature at each end and touching other bars with it whilst held in the magnetic meridian in the line of the inclined needle.

It was shown by Savery that his artificial magnets were preferable to loadstones. The first recorded attempt to make artificial magnets is credited to one John Sellers, believed to be the author of "The Practical Navigator," of which the earliest edition appeared in 1669. An "Answer to Some Magnetical Inquiries Proposed in (the preceding) No. 23, pp. 423-424," will be found in No. 26, page 478, vol. II., of the *Philosophical Transactions*; and at page 601, vol. II., of the abridgements. Reference is likewise made to this invention of Sellers at vol. I., page 86, of the "Memoirs of the Royal Society," London, 1739, and in a paper by Réaumur, in the "Mémoirs de l'Académie Francaise," for the year 1723.

See his "Magnetical Observations and Experiments," also *Phil. Trans.*, vol. XXXVI., page 295; Geo. Adams, "Essay on Electricity," 1785, p. 451.

A. D. 1731.—On the 25th of November the Royal Society were honored by a visit from the Prince of Wales and the Duke of Lorraine, the last named being enrolled as a member during the evening. Experiments were performed "On the strength of Lord Paisley's loadstone," "On Dr. Frobenius's phlogiston," and "On the electrical observations of Mr. Stephen Grey." The latter which, it is said, "succeeded notwithstanding the largeness of the company," showed the facility with which electricity passes through great lengths of conductors and are worth noting as being the first of their nature.

A. D. 1732.——Régnault (Le Père Noël) gives in "Les Entretiens Physiques, etc.," vol. I., Nos. 15 and 16, the tables of the declination at Paris from the years 1600 to 1730, and treats at length of the merits of the loadstone and of the magnetic needle.

In vols. II., IV. and V. he discourses about the extent of the magnetic fluid and explains the phenomena of meteors, St. Elmo's fire, thunder, etc., besides recording the experiments of Grey, Dufay and others.

A. D. 1733.——Dufay (Charles François de C.), French scientist and superintendent of the *Jardin du Roi*, now the *Jardin des Plantes*, of Paris (in which latter position he was succeeded by Buffon), communicates to the French Academy of Sciences the history of electricity brought down to the year 1732. (*Dantzick Memoirs*, vol. I., p. 195.)

He is said to have originated the theory of two kinds of electricity permeating matter and producing all the known phenomena of attraction, repulsion and induction, though the honor of this important discovery should be shared by White, who was associated at one time with Grey and who, it appears, independently discovered the fact while in England. Dufay thus announces his discovery: " . . . there are two kinds of electricity, very different from one another, one of which I call *vitreous* (positive) and the other *resinous* (negative) electricity. The first is that of glass, rock crystal, precious stones, hairs of animals, wool and many other bodies. The second is that of amber, copal, gum-lac, silk, thread, paper and a vast number of other substances. The characteristics of these two electricities are that they repel themselves and attract each other. Thus a body of the vitreous electricity repels all other bodies possessed of the vitreous, and, on the contrary, attracts all those of the resinous electricity. The resinous also repels the resinous and attracts the vitreous. From this principle one may easily deduce the explanation of a great number of the phenomena; and it is probable that this truth will lead us to the discovery of many other things." (See Franklin, A. D. 1752, and Symmer, A. D. 1759.)

Upon repeating Grey's experiments, Dufay observed that, by wetting pack thread, electricity was more readily transmitted through it. He was enabled thus easily to convey the fluid a distance of 1,256 feet, though the wind was high and although the line made eight returns.

See Priestley, "History and Present State of Electricity, 1775, period IV., pp. 43–54; Sturgeon, *Lectures*, 1842, p. 23; "An Epitome of El. and Mag.," Phila., 1809, p. 29, *Mém. de l'Acad.* for 1733, pp. 28, 76, 83, 233–236, 251, 252; also for the years 1734 and 1737; *Phil. Trans.* for 1734.

A. D. 1733.——Winckler (Johann Heinrich), a philosopher of Wingendorf, Saxony, and professor of languages in the University of Leipsic, first uses a fixed cushion in the electric machine for applying friction instead of by means of the hand, and is, by many, believed to have been the first to suggest the use of conductors as a means of protection against lightning. (See B. C. 600.)

In March, 1745, Winckler read a paper before the Royal Society, in which he describes machines for rubbing tubes and globes, also a contrivance with which he can give his globes as many as 680 turns in a minute. Priestley states that the German electricians generally used several globes at a time and that they could excite such a prodigious power of electricity from "globes, whirled by a large wheel and rubbed with woolen cloth or a dry hand, that, if we may credit their own accounts, the blood could be drawn from the finger by an electric spark; the skin would burst and a wound appear, as if made by a caustic."

During the year 1746 Winckler made use of common electricity for telegraphic communications by the discharge of Leyden jars through very long circuits, in some of which the River Pleisse formed a part, and it may be added that Joseph Franz had previously discharged the contents of a jar through 1,500 feet of iron, while in the city of Vienna.

See *Phil. Trans.*, abridged, vol. X., pp. 272–273; Priestley, 1775, on the discoveries of the Germans, pp. 70–77; "Thoughts on the Properties," etc., Leipsic, 1744, pp. 146, 149.

A. D. 1733.——Brandt (Georg), Swedish chemist, gives in the "Memoirs of the Academy" of Upsal an account of the experiments made by him to show the possibility of imparting magnetism to substances which are not ferruginous. He proved it in the case of the metal cobalt, and during the year 1750 the able discoverer of nickel, Alex. F. de Cronstedt, showed that the latter is likewise susceptible of this property.

See Thomas, "Dic. of Biog.," 1871, vol. I., p. 428; "English Encyc.," "Biography," supplement, 1872, p. 423.

A. D. 1734.——Polinière (Pierre), French physician and member of the Society of Arts, entirely revises the fourth edition of his "Experiences de Phisique" (*sic*) originally issued in 1709. While the second volume contains but a short chapter relative to electricity, meteoric disturbance, etc., the remainder of the work gives very curious and interesting experiments with the loadstone, making allusion to the observations of John Keill, besides treating of the declination of the needle, etc.

Prof. Perry's Electric Supply Meter.*

Those who peruse the list of new patents have been made aware that Prof. Perry has for some time been engaged in the construction of a new meter, and our French contemporaries have illustrated and described the instrument from patent specifications as though it had been *un fait accompli*. The meter, in a practical form and with nearly all the latest improvements, was shown for the first time at the soirée of the Royal Society on Wednesday last. Prof. Perry informs us that he has always been of the opinion that although any man with a knowledge of electricity and mechanism could invent an instrument to integrate current or energy, it was impossible, by going outside the two principles enumerated by Prof. Ayrton or himself in 1883, to obtain a simple, that is, a cheap, lasting and accurate supply meter. These two principles were (1) let electromagnetic forces quicken or slow the time of a clock, and (2) use an electro-motor and let its motion be retarded by forces proportional to the velocity. Such forces are fluid friction when the motion is very slow, and resistance due to Foucault or eddy currents.

The present meter works on the second principle, but it has to be observed that the conditions are not simple. First, if there is more than the merest trace of ordinary solid friction in the motor, as this alters with time and other circumstances, even if balanced by a constant current torque, it destroys the accuracy of the motor. Hence the pivoting must be excellent, and all solid friction of brushes or rubbing contacts must be avoided.

Second, if mercury cups are used as brushes, two errors are introduced. The nature of the contact alters rapidly with time, the mercury getting oxidized and dirty. If anything dips into mercury there is a friction between it and the mercury at the surface which is really of the nature of a solid friction and not a fluid friction.

Again, it seems impossible to do away altogether with ordinary fluid friction. Now, at slow speeds, fluid friction follows a law which is just what is wanted, but this is not the case at high speeds. Again, it alters considerably with temperature and other conditions.

There are experimenters who have wasted thousands of pounds because they have assumed that fluid friction is proportional to the square of the speed. Now, this is the case only at high speeds, and a meter runs at all sorts of speeds. The highest speed of this meter is one revolution per second, and this is when 100 ampères are passing through it, and even at this highest speed the fluid friction follows a law not very different from proportionality to speed. When these instruments are being manufactured by well-devised and accurate machinery their very highest speed will be a crawl.

The meter exhibited is the outcome of much thought and experiment. The solid, or *quasi* solid, friction is very small; the fluid friction is still much greater than is desired, but it follows a law which is nearly right, as the speeds are small, and, besides, *all other resistance is completely masked* by an enormous Foucault current resistance. It required a considerable amount of calculation and experiment to determine just the best method of making this resistance as great as possible.

The field of the motor being F, and the current through the armature C, the turning moment is proportional to $F C$. The resisting moment is a small, nearly constant term a, due to solid friction; a term $b n$, due to fluid friction, in which n is the number of revolutions per second (b cannot be relied upon to keep quite constant, except at very small speeds), and a very important term $c F^2 n$, representing the Foucault current friction, on which great reliance may be placed. We have, then,

$$FC = a + bn + cF^2n,$$

or,

$$C = \frac{a}{F} + \frac{b}{F} - n + cFn.$$

*Continued from The Electrical World, July 4, 1891.

*From *The Electrician* (London).

It is therefore obvious that by making F as great as possible the terms $\frac{a}{F}$ and $\frac{b}{F}$ become less important in comparison with cFn.

That this result had been obtained was evidenced by the great slowing of speed of the meter for a given current when the field was increased. In use the field magnet is sufficiently saturated to make an alteration of a few volts at the field-magnet terminals of very little effect.

Fig. 1 is a section. A is the armature; it is a cylindric copper vessel, closed at its upper end except for a few holes. It is like an inverted claret glass, and is immersed in mercury, in which it revolves. It receives current from a heavy ring B of copper, the current passing through the mercury to the lower edge of A. It passes in a cylindric current sheet upward through A, and passes from A through the mercury to C, a fixed tube dipping into the mercury. At this upper part there is a quasi-solid friction, but it is very small. The armature is coated with insulating varnish everywhere, except at the places where it receives and gives out current, and at these places it is nickel plated; hence, in the field there is no current whatever through the mercury. A phosphor-bronze spindle gives motion to the counting arrangement. The spindle is in two pieces, so that the upper part may be insulated. It can be fastened rigidly to the fixed bracket when being carried about. M is ebonite. $S\ P\ Q\ R\ N$ is a cylindric or tubular magnet wound with fine wire W. The cylindric poles $S\ N$ form the two sides of the trough in which the armature revolves, and 7 or 8 watts are expended in maintaining between them an intense magnetic field. But this field is not uniform. The plan of the pole pieces, Fig. 2, shows a number of wooden plugs, between which iron poles project, so that every portion of the cylindric part of the armature passes from intense field to almost no field 10 times in every revolution, and the result is that the Foucault current friction is about 25 times the fluid friction.

In such an instrument the smaller the clearance thicknesses inside and outside A the more exact will the instrument be in its record. It can be shown that the best results are obtained when the thickness of the copper is equal to the two clearances. Until the meter is manufactured in considerable numbers the clearance will be much greater than it ought to be. In the instrument exhibited the copper was much too thin and the clearance much too great, and yet:

1. It started with 0.2 ampère. This represented the error due to solid friction.
2. From 2 ampères to 100 ampères there was only one place (namely, at 10 ampères) where the error was so great as one per cent.
3. There was nothing to alter with time.
4. Temperature errors balanced themselves.

The meter of Faure, in which a copper bell dips into mercury, is the earliest one which depended for its action on the rotation of mercury, or of a conductor suspended in it. In a patent of Edison in 1883 the identical arrangement is to be found. The development of this idea most familiar to our readers is the Ferranti meter. Here a quantity of mercury is set in rotation, and this motion is imparted to the recording train by vanes which take up its motion, as do the ebonite vanes in the Siemens water meter. Foucault currents are absent from the Ferranti meter. Again, the uniformly distributed but varying magnetic field of the Ferranti meter depends on a series winding through which the main current flows, and the friction is balanced by a shunt winding. In Prof. Perry's meter, on the other hand, the field is maintained by a shunt coil, it is not uniformly distributed, and is practically constant in strength.

The working and the theoretical accuracy of the Perry meter are the outcome of the practical study of the phenomena of fluid friction. Ever since Stokes' classical work on the viscosity of fluids, fluid friction has been treated by many mathematicians as being simply proportional to speed. This was Stokes' discovery, and is true for small speeds. Engineers, on the other hand, starting from hydraulic experiments and the resistance offered to vessels propelled through the sea at several miles an hour, have always assumed that fluid friction varies as the square of the velocity. The apparent discrepancy was finally settled, as it should be, by a beautifully simple experiment of Osborne Reynolds, who showed that a submerged jet of colored water flowing into a tank issued in a mere line at low speeds, and at a certain definite point broke up, owing to the formation of eddies. As soon as the motion thus becomes turbulent, the friction being made up of viscosity and of eddies is practically proportional to the square of the velocity. Such is the importance of accurate knowledge of mechanical forces in the construction of electrical instruments that we must give a brief account of the further investigations by Prof. Perry on the fluid friction, since they bear directly on the subject before us. The friction in this meter is practically all pure fluid friction, and, the speed being so small, it is directly proportional to the velocity. Prof. Perry has found that when a body is partly immersed in mercury the friction at the surface—that is to say, at the line of contact—between the body, the mercury and the air is of the nature of solid friction. One of the copper bells of his meter, suspended by a fine steel wire, and partly immersed in mercury, as in the Faure meter, rotated through, say, one turn, and then left, will stand in that position for hours, since the quasi-solid friction acts as a considerable leverage; but if the surface of the mercury be raised, so that the whole bell is immersed, the friction takes place only round the spindle, and at so small a radius that it is negligible. This quasi-solid friction, we understand, appears to be independent of the length of the line of contact, just as ordinary solid friction is independent of surface, but the radius at which it acts is all-important. It is satisfactory, therefore, to know something about this quasi-solid friction, since it determines the serious matter

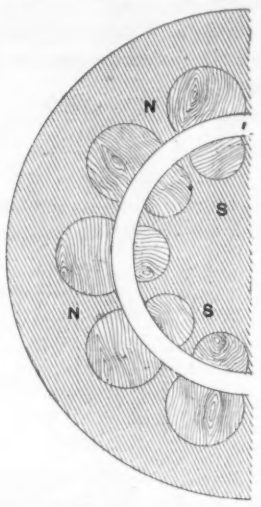


FIG. 2.—HALF HORIZONTAL SECTION THROUGH METER, SHOWING WOODEN PLUGS SEPARATING THE POLES.

of the starting current, and Prof. Perry is confident that the 0.2 ampère at which his meter begins to move is well outside the limit which will be attained in practice.

The Electrical Manufacture of Phosphorus.*

The large and increasing demand for phosphorus, not only for its main use, viz., the manufacture of matches, but for its subsidiary applications in the organic syntheses which form one branch of modern chemical industry, and in the production of many of the phosphor alloys that have recently come into vogue, has made the question of

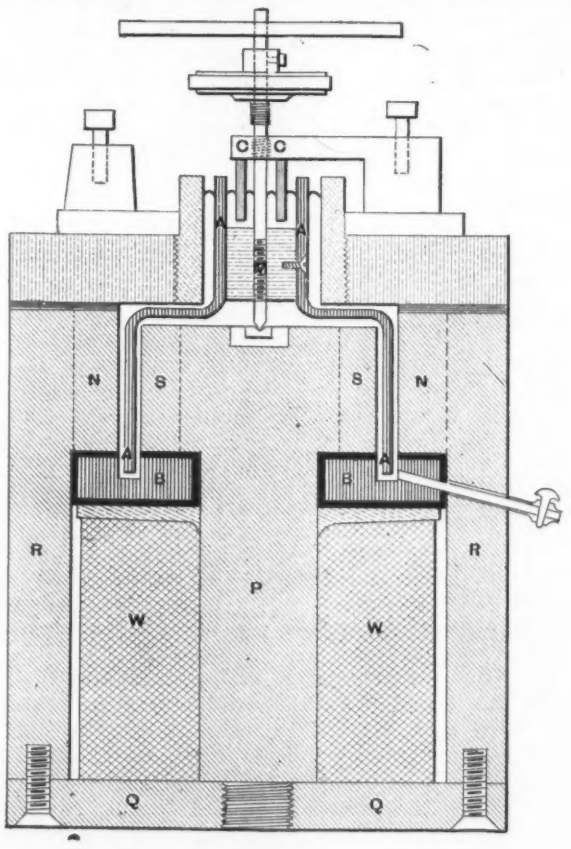


FIG. 1.—VERTICAL SECTION OF METER.

Vertical shading represents copper, diagonal shading, iron; the space filled with mercury is left white, the upper surface being shown by the rounded outlines.

its economical production of much commercial importance as well as technical interest.

On considering the method of manufacture at present generally employed, it becomes evident that the chief cost lies less in the raw materials than in that of the plant and labor necessary for the production of phosphorus from them. The outline of the process is simple and may be told in few words. Some form of calcium phosphate—formerly bones were used, but mineral phosphates are now preferred—is treated with sulphuric acid, the liberated phosphoric acid separated from the calcium sulphate produced at the same time by filtration, the solution of the former concentrated by evaporation, mixed with charcoal and heated strongly in small retorts. The carbon reduces the phosphorus from its oxide, and it, being volatile, distills, and is condensed in the usual way. As in the manufacture of sodium by the old process of reducing sodium carbonate with carbon, the chief objection to this method consists in the high temperature necessary to effect the reaction, and in the loss of a portion of the product (phosphorus in this case) through cracks in the retorts, the frequent renewal of which is also costly. The loss of phosphorus in this way is increased by the circumstance that the operation is conducted at a pressure slightly above that of the atmosphere, on account of the exit from the retorts being provided with a water-seal.

In a recent article we pointed out that there were many indications of a growing application of a principle which we then enunciated, namely, that of applying heat to the centre of a mass of material, the temperature of which it was necessary to raise for the purpose of effecting some chemical reaction, by means of an arc formed at the required spot, and instanced the Cowles furnace and the process adopted by the Electrical Construction Corporation for the manufacture of phosphorus as cases in point, at the same time indicating the advantages that accrued from such an arrangement. Since then Dr. Readman, of Edinburgh, who had independently arrived at the same idea as Messrs. Parker and Robinson, of the Electrical Construction Corporation, and who has now joined forces with them, has made public the details of his large scale experiments in a paper read before the Scottish section of the Society of Chemical Industry, and published in its journal. His earlier experiments were conducted at the works of the Cowles Company (Limited), at Milton, in Staffordshire, the large dynamo there giving 15,000 ampères at 50 to 60 volts being available for that purpose. Before they were far advanced he became aware that Messrs. Parker and Robinson were working in the same field, and the upshot of the agreement that was come to between them was the erection of large scale experimental works near Wolverhampton, where a site of about 10 acres has been obtained on the banks of a canal, and upon it have been put up boiler and engine houses and furnace sheds. The power is supplied by three Babcock and Wilcox boilers of 160 h. p. each, having a grate area of 30 square feet and total heating surface of 1,619 square feet, worked at 160 pounds. A triple expansion torpedo-boat engine by the Yarrow Shipbuilding Company, capable of generating 1,200 i. h. p. when condensing and 950 when worked without a condenser, and an Elwell-Parker alternating dynamo absorbing over 500 i. h. p., and giving, as may be desired, 5,000 ampères at 80 volts or 2,500 ampères at 160 volts, when running at 300 revolutions per minute, have been set up. The dynamo is excited by an Elwell-Parker shunt-wound machine, delivering 90 ampères at 250 volts when running at 800 revolutions per minute, a portion of the current being available for lighting and experimental work.

The process is quite simple, consisting merely in feeding in the raw materials, passing the current between suitable electrodes, as in the Cowles furnace, and collecting and condensing the volatilized phosphorus in the usual way. The weight of the slag amounts to about half the original raw materials, and can be tapped at the bottom of the furnace, while fresh raw materials are fed in at the top, so that the process is continuous, and, it is expected, may be run for days without intermission. No trouble from the escape of phosphorus vapor is to be apprehended, as the walls of the furnace may be as massive as is requisite, seeing that the heat is applied in the interior and has not to penetrate from without. It is claimed that the charges can be made to have as high a content of phosphorus as 15 per cent., and that the slag may be obtained with as little as 1 per cent., while as much as 86 per cent. of phosphorus actually passes into the condensers. The crude phosphorus thus obtained is of satisfactory quality, and can be purified by fusing under water, squeezing through washleather and treating with ammonia, and afterward with chromic acid mixture in the usual way.

The use of basic slag as a cheap phosphoric material has been tried, but without success, as the iron it contains forms a phosphide corresponding, approximately, to the formula Fe_3P_3, and containing 23.24 per cent. of phosphorus, thus leading to serious loss. Although, as already indicated, the furnaces are, with the exception of the addition of the necessary condensing arrangements, similar in construction to the Cowles, yet, on account of the need to diffuse the heat evenly throughout them, it is found advisable to limit the size considerably, those actually in use being capable of turning out about 1½ cwt. of phosphorus apiece per day.

The question of the electrodes used is naturally interesting, as these subsidiary but indispensable adjuncts sometimes prove more costly than is at first anticipated. Those made by the Cowles Company cost about 8 to 10 shillings each, but the Electrical Construction Corporation is using gas carbon, which is considerably cheaper.

It will thus be seen that though the work done hitherto is of the nature of an experiment, yet the experiment is on so large and well ordered a scale that it has more nearly reached the position of a manufacturing process than many inventions introduced far more pretentiously to public notice ever do.

The key to its successful operation is, we are convinced, to be found in the adoption of the principle of applying heat in the very spot where its usefulness is greatest, doing away at one stroke with the clumsy practice of external firing at present employed in this as in many kindred industries.

It is to be noted that nothing of the nature of electrolysis takes place. The current is alternating, and the sole reason for its use is its capability of conversion into heat at any desired place. The development of this principle, and

* From *The Electrician* (London).

its application to manufacturing processes of the most diverse kinds, may be confidently expected at no distant date.

Electrical Cable Testing.—III.

BY HENRY W. FISHER.

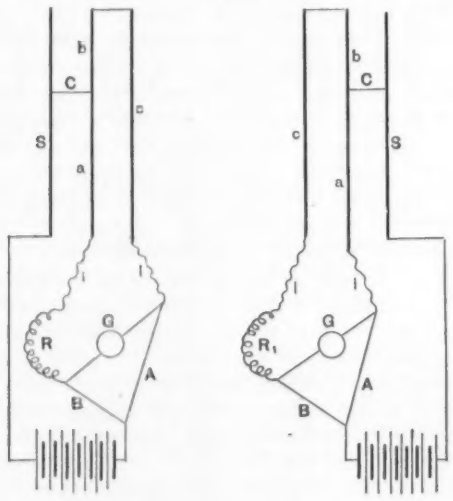
As mentioned before, grounds on cables are usually caused by moisture entering the cable through an abrasion in the lead cover or through faulty terminals. Sometimes in very wet localities the water will gradually run into the cable to a distance of 15 or 20 feet. In such a case the distance as calculated to the ground is always greater than the actual distance to the centre of the faulty portion of cable. Theoretically the measurement would locate the fault at the far end of the faulty piece of cable, and consequently, if a test is also made from the other end of the cable, the difference between the two measurements will practically give the distance moisture has entered the cable. To insure great accuracy, tests should be made from both ends of the cable, and the points midway between where these measurements come should be taken as the most probable location of the fault. If tests can only be made from one end of the cable the same result may be obtained by connecting the Wheatstone bridge to two good wires, which are in turn connected to the grounded wire and a third good wire at the distant end of the cable, the last two being looped at the testing end of the cable.

In figuring to locate the ground the first two good wires can be considered as lead wires, and their actual respective resistances can be figured by formula (1).

Another interesting fact is that if there are two bad grounds on one wire their presence may be detected by making measurements similar to the above and, if these grounds have very little resistance, each measurement will approximately locate a ground. However, as there is no way of measuring the resistance of each ground, and as the presence of two or more is not usually known at the start, the main value of testing from both ends is to show whether there are more grounds than one, or whether the faulty portion of cable is of considerable length. It will readily be seen that there is great room for originality in adapting formulæ to special cases, or in making corrections to cover leaks between wires, etc.

Where a secohmmeter is not accessible, polarizing resistances may be measured quite accurately by reversing the battery at each observation of the galvanometer.

We next come to the case in which the grounded conductor is composed of two different sizes of wire. No deviation from the methods already given is necessary till we come to the final calculation, where we figure the distance to the ground. Having calculated the resistance to the ground we proceed as follows:



Figs. 5 and 6.—Connections for Cable Testing.

Letting m = the length of the size of conductor nearest the end from which the tests are made,
and r_1 = its resistance,
letting n = the length of the other size of conductor,
and r_1 = its resistance,
R_1 = the resistance per 1,000 feet of conductor of the first size,
R_{11} = the resistance per 1,000 feet of conductor of the second size,
r = the total measured resistance,

then
$$r_1 = \frac{r \times m}{\frac{R_{11}}{R_1} n + m} \qquad (5)$$

and
$$r_{11} = \frac{r \times n}{\frac{R_1}{R_{11}} m + n}. \qquad (6)$$

If a, the resistance to the fault, is less than r_1, then the distance to the fault is

$$\frac{a}{r_1} - m;$$

but if a is more than r_1, then the distance to the fault is

$$m + \frac{a - r_1}{r_{11}} n.$$

Illustrative example:

A length of cable measuring 5,760 feet is composed of 2,700 feet of No. 18 and 3,060 feet of No. 20, both B. & S. gauge copper wire. The total measured resistance was 50.625 ohms and the resistance to the fault was 23.458 ohms. How far is the ground from the No. 18 conductor end?

From a comparative resistance table we get,

$R_1 = 6.645$ ohms and $R_{11} = 10.566$ ohms.

Substituting in formula (5) we have

$$r_1 = \frac{50.625 \times 2700}{\frac{10.566}{6.645} \times 3060 + 2700} = 18.067 \text{ ohms}$$

and substituting in (6)

$$r_{11} = \frac{50.625 \times 3060}{\frac{6.645}{10.566} 2700 + 3060} = 32.558 \text{ ohms}$$

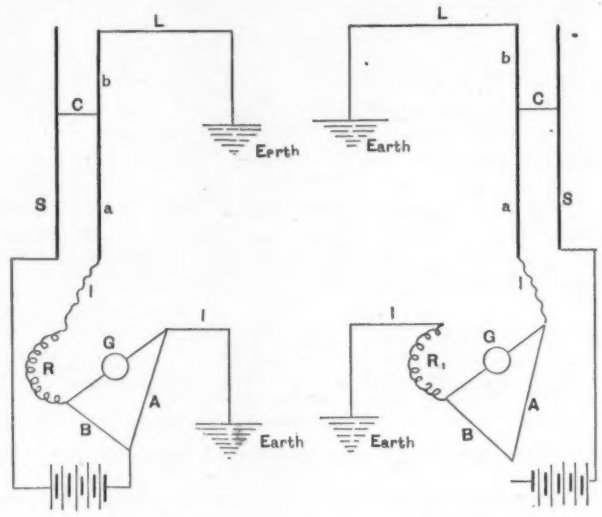
Total = 50.625 ohms

The resistance to the ground is greater than r_1; hence the distance to the ground

$$= 2700 + \frac{23.485 - 18.067}{32.558} \times 3060$$
$$= 3209 \text{ feet.}$$

CROSSES.

When water enters a cable in sufficient quantities to ground all the conductors these conductors are of necessity crossed among themselves, and the rules for finding grounds would be used in preference to those about to be given under this heading. If the wire joints connecting two sections of cable are not well insulated, or if there are any sharp points or ends of wire that may pierce the insulating covering, there is a possibility of some of the wires becoming crossed. Occasionally wires become crossed through the carbonizing of the insulating covering due to a disruptive discharge from lightning, or from some high potential circuit. From a similar cause they may be grounded.



Figs. 7 and 8.—Connections for Cable Testing.

When wires are found to be crossed at the completion of laying and jointing a cable it may be difficult to identify the ends of any particular crossed wire at both terminals of the cable. If the cable wires are made up in pairs and if no wire is crossed with its mate identification is easily rendered certain. When three or more wires are all crossed among themselves and where the resistance of the cross is very small, identification is a difficult and tedious task. Fortunately in practice this does not often occur. To render identification certain in the ordinary case of two crossed wires, the writer has devised the following simple method:

Number the crossed wires at the testing end of the cable, No. 1 and No. 2, and at the far end, No. 3 and No. 4, respectively; call the good wire No. 5; make the following four sets of connections and measure the respective resistances.

(*a*) Wires from Wheatstone bridge to No. 5 and No. 1, with No. 5 and No. 3 connected at far end of cable. (*b*) Wires from Wheatstone bridge to No. 5 and No. 1, with No. 5 and No. 4 connected at far end of cable. (*c*) Wires from Wheatstone bridge to No. 5 and No. 2, with No. 5 and No. 4 connected at far end of cable. (*d*) Wires from Wheatstone bridge to No. 5 and No. 2, with No. 5 and No. 3 connected at the far end of cable.

Let R', R'', R''', R'''' stand for the measured resistances; if $R' + R'''$ is less than $R'' + R''''$, then No. 1 and No. 3 are one wire, No. 2 and No. 4 the other wire; while, if $R' + R'''$ is greater than $R'' + R''''$, No. 1 and No. 4 are one wire and No. 2 and No. 3 the other; if the resistance of the cross is constant, its value is one-half the difference between $R' + R'''$ and $R'' + R''''$.

The crossed wires should then be tagged correspondingly at both ends of the cable. If the resistance of the cross is nothing it will not matter which ends are used in making the test to locate the cross. The same ends, however, must be used throughout the test.

Illustrative example:

Following the order given in the above method the resistances were:

$R' = 23.47$ ohms, $R'' = 23.15$ ohms, $R''' = 23.55$ ohms, $R'''' = 23.09$ ohms; which numbers belong to corresponding wires; what is the resistance of the cross?

$R' + R''' = 47.02$ ohms.
$R'' + R'''' = 46.24$ "

Difference... .78 ohm.

Resistance of cross $\frac{.78}{2} = .39$ ohm

As $R' + R'''$ is greater than $R'' + R''''$, No. 1 and No. 4 are one wire and No. 2 and No. 3 the other.

The methods for locating crossed wires are almost identical with those already given under "Locating Grounds," hence we will speak of them briefly.

Where two good wires in addition to the crossed wires are accessible, determine first of all the exact resistance of one of the crossed wires by making three combination resistance measurements between the crossed wire and the two good wires, and then figure the resistance of the crossed wire from formula (1). Then make the connections shown in Fig. 5, where a b is the crossed wire whose resistance is known and S the wire that is crossed with it at C; l l are the lead wires, A and B the resistances in the bridge, R the rheostat resistance, and G the galvanometer.

It will be noticed that one side of the battery goes to the arms of the bridge, while the other is connected to the crossed wire S.

Letting the letters stand for the resistances of the various parts and letting d = the resistance of the crossed wire, we have as the resistance to the cross,

$$a = \frac{B(d + c + l) - A(l + R)}{A + B}, \qquad (7)$$

and reversing the leads as is shown in figure (6) we have by the check method

$$a = \frac{A(d + c + l + R_1) - B l}{A + B} \qquad (8)$$

Finally the distance to the cross

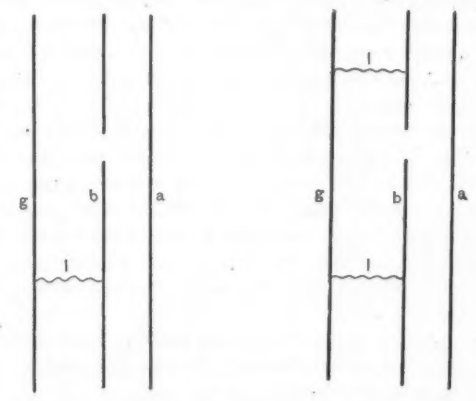
$$= \frac{a}{d} D,$$

where D = the length of the crossed wire.

In making these tests the writer usually proceeds as follows:

Resistance measurements are made first of the lead wires, second of the two good wires, third of a good wire and the faulty wire, fourth of the other good wire and the faulty wire. Then the side of the battery which does not go to the arms of the bridge is connected to the crossed wire, and as soon as a balance is obtained R, the resistance in the box, is recorded, whereupon the lead wires are reversed, and R is obtained similarly. These measurements, following as they do one after another, can be made rapidly. Of course the resistance of the leads is included in the second, third and fourth resistance measurements as they are recorded. Subtracting one-half the resistance of the leads from the fourth measurement gives the value of the term $(d + c + l)$ in the two above formulæ. The same plan of procedure is used in locating grounds, only of course the battery wire is connected to ground instead of to the crossed wire.

When only one good wire is accessible and that wire is of the same general dimensions as the crossed wire, the approximate resistance of the crossed wire may be found by taking one-half the combined resistance of the two wires, after which proceed in a manner similar to that just given for finding the resistance to the cross and calculating the distance to it.



Figs. 9 and 10.—Connections for Cable Testing.

Where no good wire is accessible, and where the resistance of the cross does not vary or else can be kept practically constant by means of a secohmmeter or by continually reversing the battery, the resistance to the cross can be found by the following method:

Connect the lead wires from the Wheatstone bridge to the crossed wires and measure the resistance of the circuit. Proceed to the other end of the cable and do likewise, using the same lead wires or ones of an equal resistance. Letting R = the first measured resistance and R_1 the second measured resistance, and letting R_{11} = the resistance of one of the crossed wires, then for the resistance to the fault we have

$$A = \frac{R + 2R_{11} - R_1}{4}, \qquad (9)$$

and the distance to the fault from the end where the first measurement was made is,

$$\frac{A}{K} D.$$

R_{11} is calculated by multiplying the resistance per foot of the conductor in question by the length of the conductor in feet.

The advantage of this method is that it can be used when one of the conductors is grounded. It cannot, however, be used where the crossed conductors are not of the same general dimensions.

If neither of the crossed wires is grounded the following method will be found more convenient than the above, as all the measurements are made from one end of the cable. Fig. 7 shows what connections have to be made. It will be noticed that the crossed wire is grounded by the wire L at the far end of the cable, while at the near end one lead wire is connected to the crossed wire and the other is grounded. Both these grounds should be made carefully and thoroughly, so that the resistance of earth may be neglected. The resistance of the wire L should be measured before or after the test.

Then with the connections as shown in Fig. 7.

$$a = \frac{B\,(d + L + l) - A\,(l + R}{A + B} \qquad (10)$$

and by the check method shown in Fig. 8.

$$a = \frac{A\,(d + L + l + R_1) - B\,l}{A + B}. \qquad (11)$$

To find d connect the lead wires from the Wheatstone bridge to the crossed wire and to the ground, ground the other end of the crossed wire through L and measure the resistance of the circuit in the ordinary manner.

Letting r = this resistance, we have,

$$d = r - (l + L),$$

and, as before, the distance to the ground

$$= \frac{a}{d} D.$$

It will readily be seen that where no good wire is accessible and where the crossed wires are not grounded, the earth can be used in lieu of the good wire in the method given for identifying the respective ends of each crossed wire.

These methods are so similar to those given under "Locating Grounds" that it is thought unnecessary to add any illustrative examples.

OPEN WIRES.

It is with a good deal of hesitancy that the writer takes up the subject of locating breaks in wires. It the insulation resistance of the open wire is over 10 or 15 megohms, and if the resistance of the break is over 50 megohms, the fault can be located quite accurately and easily. But where we have much lower resistances than the above, the matter may become quite complicated, requiring the use of logarithms or exponential equations which are out of place in these articles.

While the resistance of a break is usually very high, the insulation resistance of the open wire may very often be quite low.

The writer will first take up the simpler cases in which the resistances are very high, and afterward a few of the more difficult ones, that are likely to occur in practice.

Where one good wire of high insulation is accessible all the measurements can be made from one end of the cable. The insulation resistances of both ends of the open wire must be measured first. That of the near end is found in the manner given under "Insulation Measurements." To find the insulation resistance of the other end connect the good wire to it and read the insulation deflection, subtract the deflection obtained for the good wire alone from this and divide the constant of the galvanometer by the remainder.

If both these insulation resistances are high the following measurement will show whether the resistance of the break is high, but it will not necessarily give its exact resistance.

Connect one of the lead wires to the open wire and the other to the good wire, which in turn is connected to the openwire at the far end of the cable, then measure the resistance by the insulation resistance method. If this resistance is also very high the break can be located thus:

Set up the instruments in a manner similar to that given under "Electrostatic Capacity Tests," and take three throws,

1st, on the good wire connected to the open wire at the far end of the cable;

2d, on the good wire alone;

3d, on the open wire at the near end of the cable.

Letting t, t_1 and t_{11} equal the respective throws and letting D equal the total length of the open wire,

$$\text{then the distance to break} = \frac{t_{11}}{t\,t_1 + t_{11}} D. \qquad (12)$$

Illustrative example:

The throw on the good wire connected to the distant portion of the broken wire was 273.

The throw on the good wire was 165.

The throw on the near end of the broken wire was 58.

The length of cable measured 4,940 feet; what was the distance to the break?

$$\text{The distance to break} = \frac{58}{273 - 165 + 58} \times 4940$$
$$= 1726 \text{ feet.}$$

Where no good wire is accessible it will be necessary to make measurements from both ends of the cable. The insulation resistance from one end of the broken wire should be determined first. If this is high the resistance of the break can be measured by making an insulation test with the following connections: One lead wire to the end of the open conductor and the other lead wire to ground, the other end of the open wire being grounded at the far end of the cable.

Then arrange the apparatus for electrostatic capacity measurement and take two throws, one on the cable and one on the condenser. Call these throws t and c respectively. Next, set up the apparatus at the other end of the cable and after making an insulation test of that end of the broken wire, take a throw on it and one on the same condenser. Letting t_1 and c_1 represent these throws respectively, and as before letting D = the total length of the broken wire, we have as the distance to the break from the first end,

$$\frac{t \times D}{\frac{c}{c_1} t_1 + t} \qquad (13)$$

The previous remarks relative to the insulation of the broken wire and the resistance of the brake are applicable here also.

Illustrative example:

$t = 313$, $t_1 = 214.5$, $D = 15740$ feet.
$c = 342.5$, $c_1 = 335$.

$$\text{Distance to break} = \frac{313 \times 15740}{\frac{342.5}{335} 214.5 + 313}$$
$$= 9255 \text{ feet.}$$

If very great accuracy is desired a multiple-series condenser should be used, and the capacity inserted should be about equal to that of the section of the broken wire under test. In addition to this it is well to have all the deflections about equal, and this can be done by proportioning the amount of battery used so as to give nearly equivalent deflections. It must, however, be understood here that the same amount of battery must be used throughout the tests at either end, but it is not necessary to use the same amount at one end that was used at the other. Under these conditions the formula just given becomes

$$\text{Distance to break} = \frac{t \times D}{\frac{c \times K_1}{c_1 \times K} t_1 + t}, \qquad (14)$$

where K is the capacity that gives a throw c;
K_1 " " " " " " c_1.

Having lightly touched upon the methods for locating breaks when the conditions are most favorable for accurate work, the writer will now take up a few cases that are likely to confront the electrician in actual practice.

These are shown in Figs. 9, 10, 11, 12 and 13, and it may be well to discuss the effects produced upon the measurements in each case separately. In all the figures g represents ground, b the broken wire and a the good wire.

In Fig. 9 a leak l is represented between one section of the broken wire and ground. Consequently a throw taken from that section will be less than the true throw, on account of some of the charge having escaped through the leak l during the short interval of time required for the discharging key to break and make contact. Experiments made with the ordinary discharging key showed that with a leak of one megohm the falling off of the deflection may be considerable, while for ten megohms no appreciable decrease was noticed. In order to be able to correct for this discrepancy the writer has proposed the following method:

Take three throws as follows:

First, on the partially faulty open wire;

Second, on the above and a condenser in parallel with it;

Third, on the condenser alone.

Letting t, t_1 and t_{11} equal these throws respectively, then the approximate corrected throw for the open wire is,

$$\frac{t t_{11}}{t_1 - t}. \qquad (15)$$

The writer has obtained some very good results with this formula. It is absolutely correct where the capacity of the condenser equals that of the open wire and this is rendered practically possible by the use of a multiple-series condenser. It might be in place here to state that the formula is based upon the assumption that the insulation resistance of the open wire does not change thoughout the tests, and that the period of time between break and make of the discharging key is the same in each test. By exercising a little care these conditions can easily be realized. Having thus obtained the true throw for one end of the open wire, that for the other end can be found, as previously stated, by either measuring it from the other end or by means of a good wire which is connected to it. Then, to find the distance to the break from the first end, multiply the total length of the broken wire by the first throw, and divide the product by the sum of the throws. If the throws from the various wires in the same cable have about the same value, and this is usually the case when all the other conductors are grounded temporarily at one end, the distance to the break can be found by simply making a measurement of the throw on one end of the open wire and on a good wire, and then multiplying the total distance by the first throw divided by the second.

Fig. 10 shows a leak on each end of the broken wire and here it is only necessary to find the true throws by formula 15 and then figure the distance to the break as is above described.

On Electrical Evaporation.*

BY WILLIAM CROOKES, F. R. S.

It well known that when a vacuum tube is furnished with internal platinum electrodes, the adjacent glass, especially near the negative pole, speedily becomes blackened, owing to the deposition of metallic platinum. The passage of the induction current greatly stimulates the motion of the residual gaseous molecules; those condensed upon and in the immediate neighborhood of the negative pole are shot away at an immense speed in almost straight lines, the speed varying with the degree of exhaustion and with the intensity of the induced current. Platinum being used for the negative pole, not only are the gaseous molecules shot away from the electrode, but the passage of the current so affects the normal molecular motions of the metal as to remove some of the molecules from the sphere of attraction of the mass, causing them to fly off with the stream of gaseous molecules proceeding from the negative pole, and to adhere to any object near it. This property was, I believe, first pointed out by Dr. Wright, of Yale College, and some interesting experiments are described by him in *The American Journal of Science and Arts.*† The process has been much used for the production of small mirrors for physical apparatus.

This electric volatilization or evaporation is very similar to ordinary evaporation by the agency of heat. Cohesion in solids varies according to physical and chemical constitution; thus every kind of solid matter requires to be raised to a certain temperature before the molecules lose their fixity of position and are rendered liquid, a result which is reached at widely different temperatures. If we consider a liquid at atmospheric pressure—say, for instance, a basin of water in an open room—at molecular distances the boundary surface between the liquid and the superincumbent gas will not be a plane, but turbulent like a stormy ocean. The molecules at the surface of the liquid dart to and fro, rebound from their neighbors, and fly off in every direction. Their initial velocity may be either accelerated or retarded, according to the direction of impact. The result of a collision may drive a molecule in such a direction that it remains part and parcel of the liquid; on the other hand, it may be sent upward without any diminution of speed, and it will then be carried beyond the range of attraction of neighboring molecules and fly off into and mingle with the superincumbent gas. If a molecule of the liquid has been driven at an angle with a velocity not sufficient to carry it beyond the range of the molecular attraction of the liquid, it may escape, since, in its excursion upward a gaseous molecule may strike it in the right direction, and its temporary visit may be converted into permanent residence.

The intrinsic velocity of the molecules is intensified by heat and diminished by cold. If, therefore, we raise the temperature of the water without materially increasing that of the surrounding air, the excursions of the molecules of the liquid are rendered longer and the force of impact greater, and thus the escape of molecules into the upper region of gas is increased, and we say that evaporation is augmented.

If the initial velocities of the liquid molecules can be increased by any other means than by raising the temperature, so that their escape into the gas is rendered more rapid, the result may be called "evaporation" just as well as if heat had been applied.

Hitherto I have spoken of a liquid evaporating into a gas; but the same reasoning applies equally to a solid body. But while a solid body like platinum requires an intense heat to enable its upper stratum of molecules to pass beyond the sphere of attraction of the neighboring molecules, experiment shows that a very moderate amount of negative electrification superadds sufficient energy to enable the upper stratum of metallic molecules to fly beyond the attractive power of the rest of the metal.

If a gaseous medium exists above the liquid or solid, it prevents to some degree the molecules from flying off. Thus both ordinary and electrical evaporation are more rapid in a vacuum than at the ordinary atmospheric pressure.

I have recently made some experiments upon the evaporation of different substances under the electric stress.

Evaporation of Water.—A delicate balance was taken, and two very shallow porcelain dishes were filled with acidulated water and balanced on the pans. Dipping into each dish—touching the liquid, but not the dish—was a platinum wire, one end connected with the induction coil and the other insulated. The balance was left free to move, but was not swinging, the pointer resting at the centre of the scale. The water in connection with the coil was first made positive. After 1¼ hours there was scarcely any difference between the weight of the insulated water and that which had been exposed to the positive current. Equilibrium being restored, the current was reversed, the negative current being kept on the dish for two hours. At the end of this time the electrified water was decidedly lighter. After having again restored equilibrium, the electrification of the dishes was reversed, *i. e.*, the one that had before been insulated was made negative and the other one was insulated. In an hour the electrified water had become decidedly lighter than the insulated water. The

*A paper read before the Royal Society of London.
† Third Series, vol. 12, p. 49, January, 1877, and vol. 14, p. 169, September, 1877.

experiment was performed in a room of uniform temperature, and any draught was prevented by the glass case of the balance. In a subsequent experiment in which the quantities were weighed, it was found that negatively electrified water lost in 1½ hours $\frac{1}{1000}$th part of its weight more than did insulated water.

This experiment shows that the disturbing influence which assists evaporation is peculiar to the negative pole even at atmospheric pressures.

The metal cadmium was next experimented upon.

Evaporation of Cadmium.—If the flying off of the metal of the negative pole is similar to evaporation or volatilization, the operation should be accelerated by heat.

A tube was made as shown in Fig. 1. *A* and *B* are the platinum poles sealed through the glass; *C* and *D* are two blocks of metallic cadmium of the same size and weight. The piece *C* is in contact with the pole *B*, which in the experiment was always kept negative, the pole *A* being positive. When the exhaustion was such that the passage of the current gave green phosphorescence over the glass, heat was applied simultaneously to both ends of the U-shaped tube by means of a gas burner and air bath, so that one piece of cadmium was at the same temperature as the other. The current was then applied and was kept on for about an hour, and it was remarkable that no metal was deposited in the neighborhood of the positive pole, the surrounding portion of the tube being quite clean, while

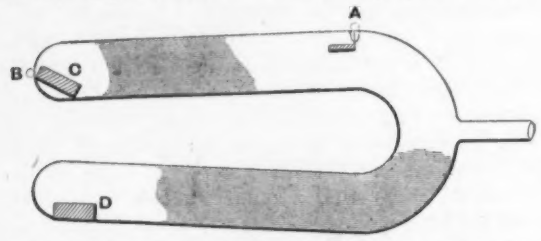


Fig. 1.—Crookes' Experiments on Electrical Evaporation.

the corresponding part of the other limb of the tube, having no electrodes, was thickly coated, the appearance being shown in the drawing.

As the temperature was high, metal had distilled off from both lamps; hence there was no visible difference in the amount of the deposit in the two sides. It is evident that, to render the electrical action most visible, the temperature should be kept short of the normal volatilizing point.

In the next experiment an exactly similar tube was used; the vacuum was such that the green phosphorescence of the glass was well seen, the temperature was kept

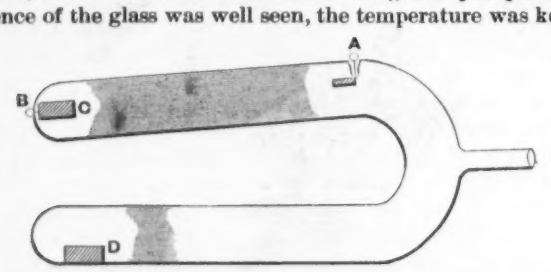


Fig. 2.—Crookes' Experiments on Electrical Evaporation.

just below the melting point of cadmium, and the current was kept on for an hour. On examining the tube at the end of this time the appearance was as seen in Fig. 2. A considerable deposit had taken place on the end of the tube near the negative pole, the space round the positive pole was clear, while in the limb of the tube where no electricity had been passing only a very little deposit of metal was seen, as shown in the figure.

The temperature in this experiment having been kept below the melting point, had no electricity been applied there would have been very little, if any, evaporation. The amplitude of the molecular oscillations was increased by the rise of temperature, but not sufficiently to allow many of the molecules to pass beyond the sphere of attraction of the mass. When, however, the current was turned on, the oscillations were increased sufficiently to carry some of the molecules beyond their spheres of attraction, and hence into the vacuous space above. As in the water experiment, this only happens at the negative pole. It would seem that, even after having been *removed* from the rest of the mass, the on-rushing stream of gaseous molecules is necessary to carry the metallic molecules away, and, as I shall presently show, even then they very quickly drop out of the ranks and deposit on the walls of the tube.

Another tube was made as shown in Fig. 3. The poles *A*, *B*, *C*, *D* were platinum wires sealed through the glass, *A* and *D* having aluminium poles covering the platinum wire. In the ends of the tube, and touching the poles *B* and *C*, were two pieces of cadmium of the same size and shape. The tube was exhausted to the phosphorescent point, and the current was turned on, *C* being made negative and *D* positive. No heat was applied. The current was kept on for about half an hour, until a good deposit of metal had been made on the glass, the appearance being as shown in Fig. 4, the glass near the pole *C* being coated with metal, while the glass round the pole *D* was clean. The outer boundary of the dark space during the experiment is shown by the dotted line *e f*.

The pole *B* was now made positive and the pole *A* negative, the current being kept on for another half hour. At the end of the time the only additional effect was a slight darkening round the lump of cadmium, in the same place as, but very much fainter than, the deposit shown in Fig. 5. This is probably due to a little leakage of negative discharge from the positive pole. The experiment shows that positive electrification does not cause the metal sensibly to volatilize.

In these experiments no estimation was made of the weight of metal removed, and the cadmium only rested by its own weight upon the platinum wires that had been sealed through the glass. To render the experiment quantitative, and at the same time to remove any disturbing effect that might be caused by heating at the point of indifferent contact, the following experiments were made:

A U-shaped tube, shown in Fig. 6, had a platinum pole sealed in each end. Six grains of pure cadmium were put

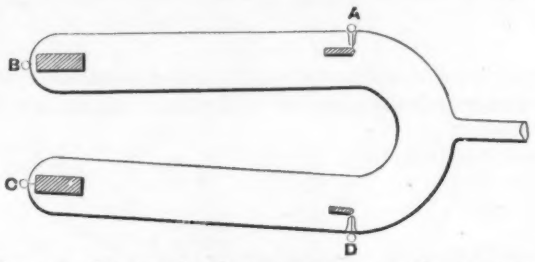
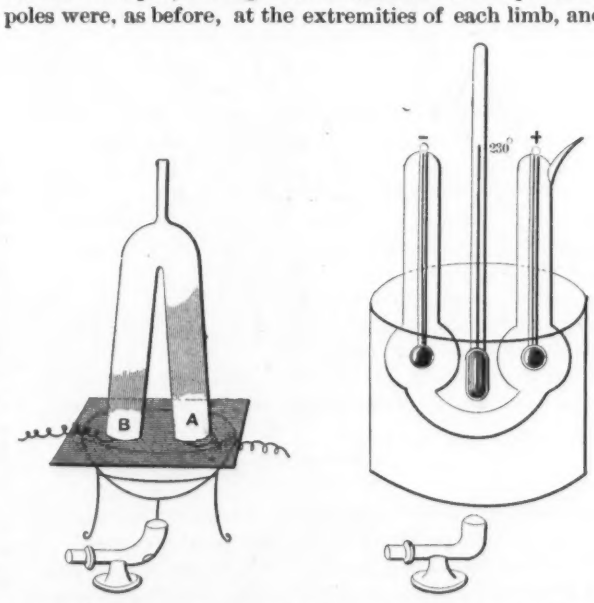


Fig. 3.—Crookes' Experiments on Electrical Evaporation.

into each limb and fused round the platinum wire. The ends of the tube were then put into an air bath and kept at a temperature of 200 degrees C. during the continuance of the experiment.* The exhaustion remained at 0.00076 millimetre, or one M. The induction current was kept going for 35 minutes, the pole *A* being negative and *B* positive. At the end of this time it was seen that most of the cadmium had disappeared from the negative pole, leaving the platinum wire clean, no metal being deposited near it, and the molecules appearing to have been shot off to a distance of about three-quarters of an inch. The appearance of the positive pole was very different; scarcely any of the cadmium had been volatilized, and the condensed metal came almost close to the pole. The tube was opened, and the remaining wires and metal were weighed. The cadmium was then dissolved off the poles in dilute acid; the residue was washed, dried and weighed:

	Positive pole.	Negative pole.
Original weight of cadmium.....	6.00 grains.	6.00 grains.
Cadmium remaining on the pole	3.65 "	0.25 "
Cadmium volatilized in 35 minutes...	2.35 grains.	5.75 grains.

The difference between the amount of cadmium driven from the two poles having proved to be so decided, another experiment was tried in a tube so arranged that the metal could be more easily weighed before and after the experiment. The apparatus is shown in Fig. 7. A tube was blown U-shaped, having a bulb in each limb. The platinum poles were, as before, at the extremities of each limb, and



Figs. 6 and 7.—Crookes' Experiments on Electrical Evaporation.

in each bulb was suspended from a small platinum hook a small lump of cadmium, the metal having been cast on to the wire. The wires were each weighed with and without the cadmium. The tube was exhausted, and the lower half of the tube was inclosed in a metal pot containing paraffin wax, the temperature being kept at 230 degrees C. during the continuance of the experiment. A deposit around the negative pole took place almost immediately, and in five minutes the bulb surrounding it was opaque with deposited metal. The positive pole, with its surrounding luminosity, could be easily seen the whole time. In 30 minutes the experiment was stopped, and after all was cold the tube was opened and the wires weighed again. The results were as follows:

	Positive pole.	Negative pole.
Original weight of cadmium.....	9.34 grains.	9.38 grains.
Weight after experiment.....	9.25 "	1.86 "
Cadmium volatilized in 30 minutes....	0.09 grains.	7.52 grains.

(To be continued.)

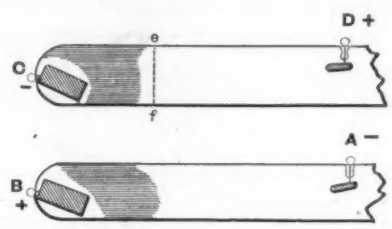
* Cadmium melts at 320 degrees and boils at 860 degrees.

Note on an Electrostatic Wattmeter.

BY MAURICE OUDIN, M. S.

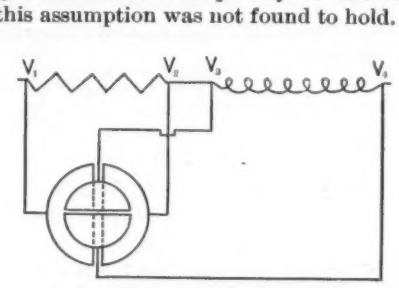
The electrometer under proper conditions is superior to any other instrument for the measurement of the power given to a circuit by an alternating current. It takes no current from the main circuit, its resistance is infinite, its inductance is zero, and it has no temperature coefficient. In the usual form of quadrant electrometer the deflections are not proportional to the energy in the circuit. This irregularity, due mainly to the shape of the needle, was always greater when the quadrants were carried to a high potential. The existence of an electrical directing current tending to restore the needle to zero was proved by M. Gouy. Parasitic electromotive forces, due to contact of dissimilar metals, is another source of error. In the Carpentier electrometer the needle and quadrants are cylindrical in shape. The bifilar suspension is replaced by a fine platinum wire and the needle is dampened by moving between the poles of a permanent magnet. The deflections are closely proportional to the energy in the circuit.

With these instruments a double reading is necessary. An electrometer giving direct readings of the electrical power—an electrostatic wattmeter, in short—would prove a great advance. Such is the instrument of Curie & Bloudlot, brought out in 1888, a modified form of which



Figs. 4 and 5.—Crookes' Experiments on Electrical Evaporation.

the writer has used. The needle is divided into two half circles insulated from each other, and the quadrants are replaced by semi-circular plates. There are thus four points comprising one system which can be connected to four different potentials. The fixed plates are joined to the ends of a non-inductive resistance intercalated in the circuit and the divided needle to the terminals of the working part of the circuit. The couple acting on the needles is theoretically proportional to the product of the differences of potential and consequently to the energy. In practice this assumption was not found to hold. With increased power given to the circuit the increase of deflection was greater than it should have been. The writer was unable to find any law connecting the power and the readings, and believes that the instrument to be of practical value must be calibrated empirically.



Electrostatic Wattmeter.

A brief description of the wattmeter may prove interesting. The movable semi-circular discs forming the divided needle were made of light aluminium foil .009 inch in thickness. In order to give stiffness the needle was fluted by means of a steel mould like the drum of an aneroidal barometer. The diameter was 2½ inches, that of the suspension wire .025 inch. The two halves were insulated from each other by a hard rubber bushing and hub, one half connected to the upper, the other to the lower suspension wire. The fixed plates were four in number, two above and two below the needle, and made of magnetized steel $\frac{5}{16}$ inch thick and 4 inches in diameter. They were fastened to two hard rubber discs, insulating each semi-circle from its neighbor and mounted on concentric brass axes, so threaded that when one was turned to elevate its plate the other was lowered a like amount; the plates could thus be separated to any distance required. Each semi-circle was connected to a binding screw, making six terminals to the apparatus. When used as a wattmeter the corresponding upper and lower fixed plates were joined together, reducing the terminals to four. The two suspension wires were 10 inches long, and could be brought to any tension required by a spring and screw. The instrument was mounted on a zinc tripod base, and protected from the disturbing effect of air currents by a brass case.

A glance at the figure will show how the connections are made. The needles are joined to V_3 and V_4, between which points the work is being used, and the fixed plates to V_1 and V_2, the terminals of the non-inductive resistance. If θ be the deflection for given differences of potential, V the capacity of the needle per unit angle, and J the coefficient of torsion of the wire, we have the expression,

$$\theta = 2\frac{V}{J}(V_3 - V_2)(V_3 - V_4). \qquad (1)$$

The moment of the couple that tends to restore a wire under torsion to its position of equilibrium is

$$W\theta = \mu \frac{d^4}{l}\theta,$$

where d is the diameter and l the length of the wire, θ the angle of divergence in radius, and μ a factor depending on the viscosity of the metal of the wire. The coefficient of the torsion of the wire

$$J = \frac{W}{\theta} = \mu \frac{d^4}{l},$$

which, substituted in equation (1), gives

$$\theta = 2\gamma \frac{l}{\mu d^4}(V_1 - V_2)(V_3 - V_4).$$

We see from the equation that the instrument may be made sensitive to any degree required by proper selection of wire and size of plates. In the instrument described silver wire was substituted for iron wire to increase the deflection, the relative values of μ being 758 and 260. Aluminium has a still higher value for μ, and its ductility allows it to be readily drawn down to any fineness. The non-inductive resistance used measured 23.1 ohms.

The instrument can be used like the Thomson quadrant electrometer, by joining the halves to the same high potential, as an homostatic or idiostatic electrometer, by connecting the fixed with the movable plates, as a differential electrometer and finally as a wattmeter.

In this last case, calling K the constant or factor of construction, we have,

$$\theta = \frac{K}{T}\int_0^T (V_1 - V_2)(V_3 - V_4)\,dt;$$

But

$$It = \frac{V_1{}^0 - V_2}{R},$$

whence

$$\theta = \frac{KR}{T}\int_o^T It\,(V_3 - V_4)\,dt.$$

As $It(V_3 - V_4)$ is the power at any instant, t the mean power is easily found to be

$$W = \frac{\theta}{K\,R}. \qquad 2)$$

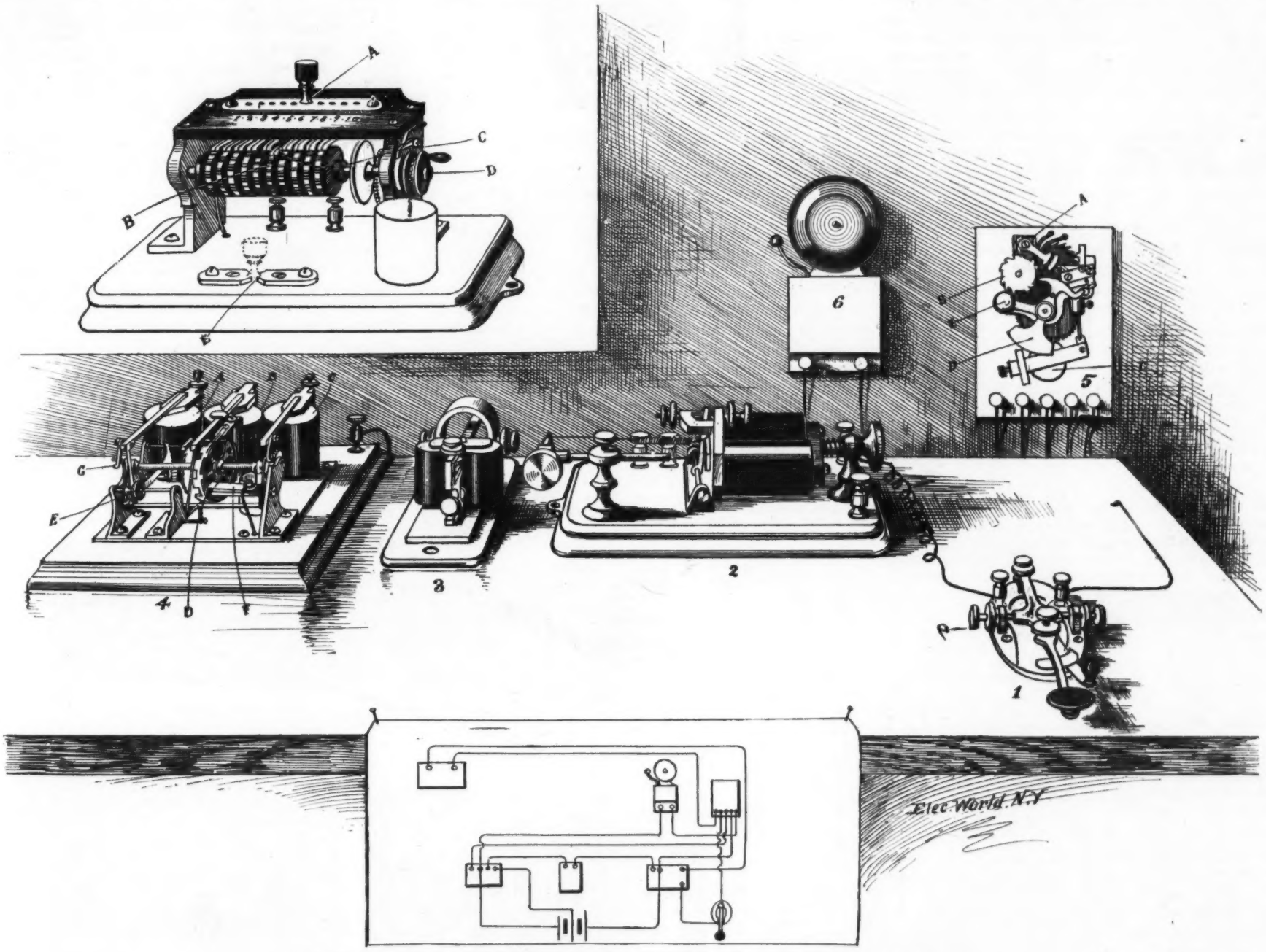
The above formula, however correct theoretically, does not hold in practice. The constant varies according to no law that could be ascertained. The main difficulty in the practical use of the instrument lies in the suspension system. After each removal from one place to another the constant has to be redetermined, so sensitive is the wattmeter to shocks and vibrations. The torsion of the wire changes with temperature but not perceptibly with tension. The utmost care must be taken in putting in a new wire that it possesses no torsion. On account of its great sensitiveness and its lack of portability the electrostatic wattmeter is undoubtedly an instrument for the laboratory rather than the workshop.

Individual Selection on Electric Circuits.

Telegraph and telephone men are apt to smile when they hear the words "individual call," for scarcely a year has passed in the last twenty without some system professing to perform this work being patented, and more or less talked about. As in many other cases, however, there were some grains of wheat in the mass of chaff, and it now appears that for the past two years a number of skilled and experienced experts, guided by competent direction, have been quietly but industriously cultivating these grains into what promises to be a useful and valuable crop of sound wheat.

The Electric Secret Service Company, whose main offices are at 45 Broadway, New York, was organized a couple of years ago for the purpose of consolidating all the practicable inventions relating to this art and bringing them up to a point where they would indeed be capable of performing the highly important work which the inventors had in view when they gave their attention to the subject. Composed of a few prominent capitalists of New York, Boston and the West, men largely interested in railroad and electrical undertakings, the company adopted the policy of perfecting the machines it proposed to offer to the various fields of electrical activity, and securing ample protection both in this country and abroad for its property, before going into the market for commercial purposes. The managers consider that this preparatory work has now been thoroughly accomplished, since they are now bringing out various forms of instruments for practical use in railroad and other work, and have obtained, in addition to a dozen domestic patents, similar protection in no less than fifteen foreign countries. Beginning with the patents of E. R. Gill, Jr., and Adin A. Hatch, two young inventors of Kansas City, and subsequently acquiring the earlier patent of Samuel Earl Mosher, the well-known inventor, of Chillicothe, O., the company has had the assistance of Messrs. S. S. Bogart, Charles J. Kintner, Wm. C. Moore, Geo. L. Foote and Robb MacKie in reducing the designs of the original inventors to the conditions demanded by actual practice. All this experimental work has been done with the co-operation and suggestions of gentlemen prominent in the practical departments of railroad and electric-light work, so that the company confidently believes that the system which it now offers to the public meets all the requirements, whether economical, mechanical or electrical, of the every-day service for which it is intended.

The machines which the company is now busily engaged in putting out are more especially adapted for railroad work. Our illustrations show a complete set of the company's system, with diagrams of their connections. Referring to them; Fig. 1 is an ordinary Morse key, Fig. 2, a Western Union relay, Fig. 3, an ordinary sounder, all set up for regular telegraph work. Fig. 6 is a vibrating gong, Fig. 4 is the "combination lock," or selecting instrument, which is added to the usual telegraph set for the purpose of enabling the train dispatcher, superintendent or other official to reach the individual office desired, and Fig. 5 is the "automatic answer-back," or return signal, through which the lock works, and which returns to the calling office the signal that the work required has been done. The unnumbered cut in the upper corner is a mechanical transmitter. A diagram of local connection is also given. It will be seen that the insertion of these instruments causes no derangement of the lines in an office and requires no alteration. The main line connection for the answer-back can be taken by a loop of either the key or relay wire, and when made no additional resistance is offered to the main line. As will be seen by reference to the diagrams the main line is intact and the connections are made by the relay armature thus operating the lock, answer-back, gong and sounder in the local circuit. No extra battery is called for, in addition to that used at a station, beyond the extra cell required for ringing a gong. Consequently the addition of the lock with its answer-back and signal gong involves no expense or disturbance of business for installation.



INDIVIDUAL CALL SYSTEM OF THE ELECTRIC SECRET SERVICE COMPANY.

The method of operation is equally simple. On a line of railway telegraph, for example, each station (or so many of them as may be wished) is fitted up with a lock, answer-back and continuous ringing gong. The lock at every station has its controlling wheel cut to a combination which differs from that of every other lock on the same line. Such combination may be made either of numerals or of Morse characters, or the two mixed, thus affording an indefinite number of individual calls. The answer-back at each station is furnished with a wheel cut with a station signal, and such other letters as may be desired, for example, "OK, SX," etc. No other preparation is necessary at the stations.

At the train dispatcher's or superintendent's office no special arrangements are necessary, since any of the locks along the line may be worked with the ordinary key; but the company suggests the use of its automatic transmitter,

which can be attached to the line without trouble or preparation of any kind. Let us suppose, for instance, that a dispatcher wishes to call Grantville, and that the combination of the lock at that station is 2-3-1-2. If he prefers to use the key, he has only to send out - -, space, - - -, space, - space, - -, and close the key. Simultaneously the wheel of the Grantville lock revolves until, at the completion of the signal, it closes its local circuit and releases the trip *C* on the answer-back, the wheel of which begins to revolve. As it revolves the signal "OK-GT" (or whatever it is) comes back over the line to the dispatcher's office and is repeated by his sounder. The revolution of the answer-back wheel closes the gong circuit, and the gong continues to ring until the operator comes in and shuts it off by the crank *E*. In shutting it off he sets the wheel of the answer-back ready for the next signal, so that no forgetfulness or carelessness can leave the dispatcher without the means of knowing that his call has taken effect. But a train dispatcher is apt to be a busy man, and, although only 10 seconds are required to send the call by a key, he may wish to save these. To this end the company furnishes each dispatcher's office with an automatic transmitter, one form of which is shown in our corner illustration. In this case the revolving cylinder *B* of the transmitter carries a series of insulated discs corresponding in number and combinations with the locks at the several stations. A plug, *A*, is inserted in the switch plate at the hole corresponding to the Grantville call, say No. 6, and the crank of the transmitter is turned. Nothing else is necessary. The cylinder revolves with disc No. 6 alone in contact. The call goes over the line to Grantville. The gong is set ringing and the answer-back comes back over the line to the dispatcher. The saving of trouble is not the only advantage; the call sent out is mathematically accurate. There is no chance for a mistake in sending the combination. The operators at the various stations may likewise be furnished with cards giving the respective combination "calls," and thus be enabled to ring up one another by means of their keys whenever occasion demands.

The company's aim has been to produce a lock free from all mechanical complications, and yet one which will work accurately under all conditions likely to arise in railway service. A reference to Figs. 4 and 5 will show the simplicity of the machine. The answer-back requires no explanation. The plate *D* is released when the combination on the lock is completed by a trip worked by the magnet *C*. It revolves with the wheel *B*, closes the contact points *A* and the operator shuts off the bell by turning the crank *E*. The lock itself, Fig. 4, consists of three single magnets with their corresponding armatures *A*, *B* and *C*. Armature *C* gives a progressive step-by-step motion to the shaft *G* corresponding with the impulses of the signal sent. Armature *A* with its escapement controls the shaft's motion so that it cannot vary either as to space or time from the impulses sent. Armature *B* is furnished with a pin which engages the contact surfaces of the combination wheel *D* attached to the shaft *G*. This pin makes contact with surfaces so long as they correspond with the duration of the signals; but when the signal varies from the combination cut on the wheel the pin drops through the next space and the wheel is instantly returned to zero, or its starting point, and the signal is not completed. This arrangement secures absolute accuracy of operation and effectively prevents the wheel completing a revolution and thus closing the contact point *F* unless the signal is exactly the one intended for that particular lock.

This system has been subjected to exhaustive tests over several railroad lines, and it is said that it has never failed to perform its work thus far. The signal for one station cannot possibly operate any lock except that one exactly corresponding in all of its elements to the signal sent, and no amount of Morse writing will cause them to creep over and give a signal when none is intended.

The company considers that in presenting its system for general use it is furnishing an addition to the telegraph equipment of the country, particularly on railroads, which must result in greatly increased convenience as well as large economy in operation. On lines where the operator has other duties to perform, which call him away from his table, the use of his lock affords a sure and easy method of summoning him at any time. At stations where occasional night service is required and yet where the business does not warrant the keeping of an extra night operator, the lock furnishes a quick and certain means of summoning an operator to his table, even should he be on another floor or in another house. The fact that in shutting off his bell he sets the return signal for the next call and that his dispatcher is thus always informed that the gong at the outlying station is ringing, will prevent a sleepy operator from becoming indifferent, through habitual use, to the call of the gong. Another application easily made is for the emergency and train crews at yards and

Battery Gauge.

terminals, thus dispensing with a messenger, whose rounds consume much valuable time. Other special uses may be made of the system in cases where such are required.

An easily effected change in the connections of the lock and answer-back permits the dispatcher to cut out at will any stations along the line and telegraph past them to a particular station without the knowledge of intermediate ones. This is done by furnishing a general or master signal for all the locks by means of which every lock is cut out at the same time. The dispatcher then, by sending the signal of the single office he wishes to address, cuts that in while all others remain out. A repetition of the master signal will cut them all in again.

Such are some of the uses to which the company is now engaged in putting these arrangements. In addition to these it has elaborated a complete system for cutting in and out arc lamps upon any circuit by means of a transmitter located in the central station. This promises to be of much utility, particularly in the smaller cities and towns where it is not practicable to confine the different classes of lighting to separate dynamos. A wider application is also proposed in connection with railroad signaling, whereby a train dispatcher or superintendent shall be enabled to set any signal, whatever the distance, and restore the same with entire confidence that the work has been effectively performed. Other uses still have been designed in connection with the fire and alarm telegraph systems of our larger cities and with naval and military operations, but these are not as yet ready for publication.

The form of lock now being issued by the company is claimed to be free from liability to accident or derangement, and to operate regardless of distance under circumstances when, through escape on partial grounds, or excessive resistance, an ordinary sounder would fail to take Morse characters. The company states that its machines have been operated with entire success in railway service over 900 miles of line, while the specially prepared electric light appliances have extinguished and lighted individual arc lamps on a circuit carrying over 8,000 volts, without disturbing any lamp on the same line other than the one selected for operation.

Improved Battery Gauge.

The Standard Electric Time Company, of New Haven, Conn., has just put its improved pocket battery gauge on the market.

This is similar in appearance to the one formerly manufactured by this company, but the mechanical parts have been changed considerably so as to make it much stronger and less liable to damage in use or transportation.

Edison Slow Speed Motors.

The small motors built by the Edison Company were fully described and illustrated in The Electrical World of May 30, 1891. Some further details of their construction, however, are given in the accompanying table and diagram. The four sizes are wound for 120 volts potential difference, the first three being series wound and the last a plain shunt motor. The letters at the top of the dimension columns refer to the diagram. All the dimensions are given in inches and the weight in pounds:

Guaranteed h. p. at full load.	Revolutions per minute.		Net weight.	Over all.			General.				Base frame.			Pulley.		
	Light load.	Full load.		A	B	C	D	E	F	G	H	J	K	L	M	N
½	4400	2000	14.75	8¾	7⅛	7¾	5½	2⅞	5¼	4⅛	7⅛	7	¾	⅞	1⅛	5/16
¾	2900	1675	20.25	10⅛	7⅞	7⅛	6⅝	3	5½	4¾	8⅛	8	⅞	1	2⅛	⅜
1½	2500	1100	28.50	10⅞	7⅞	9¾	6⅞	4⅛	5½	5⅛	8½	8¼	⅞	1½	2¾	⅜
3	1710	1300	37.60	10¾	8	10⅛	7	4¾	6	6	9	9	1	2	3	½

The "W. B. G." Protector.

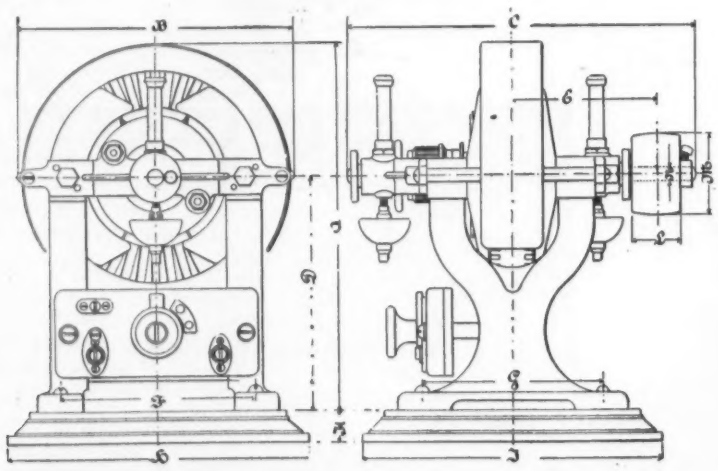
The need for protecting telephone, telegraph and other electrical instruments, including bells, switchboards and cables, from danger of damage by heavy or abnormal currents is now very generally admitted, especially in telegraph and telephone circles.

Many have attempted to supply this want, as is evidenced by the number of "protectors" and "cut-outs" now upon the market. What is needed for telephone use is a protector that will protect a station or central office against dangerous currents of all kinds, including the "sneak" variety. The "sneak" current is the most difficult one to provide against, as it is never constant, yet it is to this current that most of the damage to telephone apparatus is due.

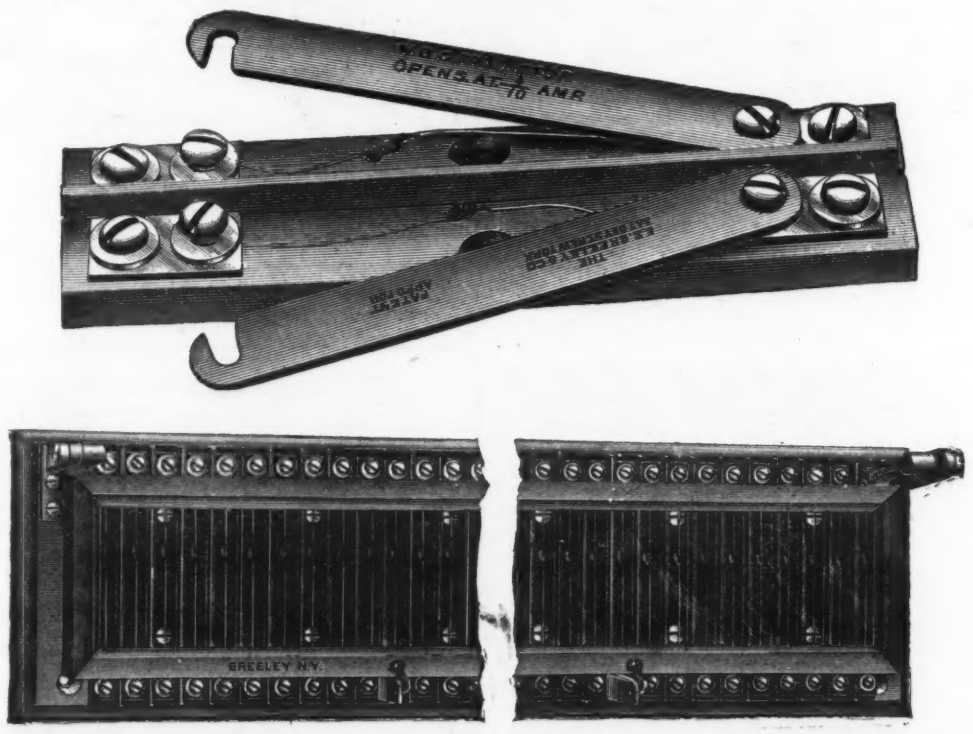
On this page we publish cuts of the "W. B. G." Protector. The inventors of this device are practical telegraph and telephone men and understand fully the necessity nowadays of a thoroughly reliable protector for telephone and telegraph stations and instruments. Of course any device that would be efficient in these two lines of electrical business would be equally so in others, such as burglar alarms, messenger and clock service, and in all cases where apparatus is exposed to damage from heavy or abnormal currents. The protectors are mounted 1, 2 and 3 on a base (which is of vulcanized fibre) and in sections of 50, as shown in the cuts.

The single, double and triple protectors are intended for use at telephone subscribers' stations and are mounted to accommodate "single," "metallic" and "law system" working. The sections of 50 are intended for use at central offices or any place where a large number of wires enter.

The main feature of the invention is the manner in which the fuse is melted by the generation of heat in the small coil of comparatively high resistance wire, which is wound upon one end of the fuse and which is part of the circuit. The coil is formed of German silver wire of size and length necessary to produce heat enough to melt the



DIMENSIONS OF SMALL EDISON MOTORS.



THE "W. B. G." PROTECTOR FOR TELEPHONE AND TELEGRAPH CIRCUITS.

fuse upon the passage of any current that it may be deemed desirable to have the line "open" at. For ordinary use at subscribers' stations they are wound to open the line at about four-tenths of an ampère, and for use at other palces, such as central offices, where more delicate apparatus may need protection, they are wound accordingly.

The principle upon which it operates is well known and very simple, and it is evident, therefore, that the device is a protection against the "sneak" current so destructive to electrical apparatus containing electromagnet coils of fine wire, as well as against heavy or abnormal currents.

It is also used in cable boxes, and by very simple arrangement is said to form good protection against lightning as well as strong currents.

These devices are manufactured and placed on the market by the supply house of The E. S. Greeley & Co., of New York.

Financial Intelligence.

THE ELECTRICAL STOCK MARKET.

Chicago Quotations.—Col. S. G. Lynch, broker, 153 Monroe street, Chicago, furnishes quotations on telephone and electric light stocks as follows:

Chicago	$230@$240	Cumberland	$60@ $62
Central Union	51@ 55	Wisconsin	118@ 120
Michigan	84@ 85	Bell of Missouri	160@ 165
Great Southern	30@ 32	Iowa Union	20@ 22
Colorado	31@ 36	Missouri and Kansas	54@ 56
Rocky Mountain Bell	40@ 43		

ELECTRIC LIGHT STOCKS.

Chicago Arc Light and Power	$100@$101	Chicago Edison Co.	$145@$150

AFFAIRS OF THE COMPANIES.

The St. Paul and Minneapolis Messenger and Telephone Company, of Minnesota, has elected T. D. Abbey, president; John E. Ebel, vice-president, and F. M. Schulte, secretary and treasurer.

The Erie Electric Motor Company last week decided to increase the amount of the capital stock. Plans were perfected for the proposed extension of the road. Messrs. Everett, of Cleveland, J. S. Casement, of Painesville, and other non-resident directors were present at the meeting.

The Scottdale (Pa.) Electric Light, Heat and Power Company.—At a meeting held recently for the purpose of voting to increase the capital stock, or to issue bonds to pay the indebtedness of the company, it was decided to issue 5 per cent. bonds to the amount of $10,000. The bonds will be of the denomination of $1,000, and run from one to eight years.

Edison General Electric Company.—The official statement of the North American company issued last week contains the following: "The report of the North American company submitted at its annual meeting shows that the company is actively prosecuting large street railway and electric enterprises in Milwaukee and Cincinnati; that it has concluded a contract with the Edison General Electric Company and Mr. Edison, opening the whole field of electricity as a motive power upon railways, and that it has entered upon this field under circumstances which place it in a most favorable situation for the advantageous employment of its capital."

NEW INCORPORATIONS.

The Bellevue (O.) Light and Power Company has been incorporated with a capital stock of $20,000.

The Alexandria Bay Electric Light and Power Company has been incorporated, with a capital stock of $7,500.

The Heat, Light and Power Company has been incorporated at Chicago, Ill., with a capital stock of $20,000,000. The incorporators are: David E. Davis, Theodore Barratt, Thomas Donald McKay and others.

The Santa Ana (Cal.) Gas and Electric Company has been incorporated with a capital stock of $100,000. The directors are C. M. Holmes, W. H. Spurgeon, W. S. Bartlett, C. H. Parker A. E. Parker and A. J. Judge.

The Ries Electric Specialty Company, of Baltimore, Md., has been incorporated by Elias E. Ries, Lewis S. Greenfelder, Leopold Ries, Dave Myers and O. Milton Dennis, for the manufacture, sale and installation of electrical apparatus. The capital stock is $25,000.

The Harvard (Ill.) Electric Light and Power Company has been incorporated with a capital stock of $15,000 to furnish light, heat and power, and to manufacture electrical apparatus. The incorporators are J. E. Keely, A. W. Young and E. L. Church.

The Electric Packet Company, of East St. Louis, has been incorporated with a capital stock of $7,000,000, to construct and operate boats on the Mississippi River and its tributaries. The incorporators are H. H. Liemke, J. W. Whitlesey, Gus Frey, J. R. Schmidt and H. D. O'Brien.

The Electric Dryer Company has been incorporated at Chicago, Ill., with a capital stock of $1,500,000, for the manufacture of machinery for treating water and air for laundry purposes, heating and ventilating, etc. The incorporators are John E. Brown, Edward W. Williams and William D. Rawlins.

The Marinette (Mich.) Consolidation.—The Marinette Lighting Company and the Marinette Street Railway Company have consolidated their interests and the corporate name is the Marinette Gas, Electric Light and Street Railway Company. The capital stock is $125,000, and the business will be conducted under one management.

The Oxford Central Telephone and Telegraph Company, chartered by the Maine State Legislature, organized at Paris, Me., last week, with choice of these directors: John P. Swasey, Waldo Pettengill, H. N. Bearce, A. E. Herrick, L. R. Giles, Geo. C. Wing, O. H. Hersey; Geo. A. Wilson, clerk; E. L. Tibbetts, treasurer. The directors elected Waldo Pettengill president.

The Canajoharie Electric Light Company has been incorporated at Canajoharie, N. Y., for the purpose of manufacturing and using electricity for producing light, heat and power, and in lighting streets and places in Canajoharie and Palatine Bridge. The capital is $10,000, and the directors for the first year are: William J. Arkell, Adelbert G. Richmond and Randolph Sprake, all of Canajoharie.

Th Southern Electric Company has been incorporated at Lynchburg, Va., for the manufacture of electrical apparatus, with a capital of $1,000. The incorporators are: Cecil P. Poole, Charles W. Poole, R. H. Pannill, H. Steger and A. M. Raikes, and the officers named for the first year are; President, Cecil P. Poole; vice-president, Charles W. Poole. Directors: Cecil P. Poole, Charles W. Poole, Ro. H. Pannill, H. B. Steger and A. M. Raikes,

Special Correspondence.

NEW YORK NOTES.

OFFICE OF THE ELECTRICAL WORLD,
167-177 TIMES BUILDING, NEW YORK, July 6, 1891.

Extension of Edison Lamp Works.—The Edison General Electric Company has just given out contracts for an extension of the lamp works in Harrison.

Mr. W. R. B. Willcox, who has had charge of the electrical heating department of the Electric Merchandise Company, of Chicago, was in New York this week conferring with Mr. S. Dana Greene, the consulting electrician of the Burton Heating Company, in regard to the placing of electric heaters on the market for electric street-railway use.

A Happy Event.—The engagement is announced of Mr. George Baehr, superintendent of the underground work of the Edison Electric Illuminating Company, of Brooklyn, and Miss Hannah Smyth, the Hoboken manager of the Western Union Telegraph Company. The event was celebrated at Miss Smyth's home, 282 Newark avenue, Jersey City Heights, on Thursday evening of last week.

American Institute of Electrical Engineers.—At the regular monthly meeting of Council of the American Institute of Electrical Engineers, the following delegates were appointed to attend the Frankfort Electrical Conference in accordance with a resolution adopted at the general meeting, May 21st: Carl Hering, Chairman; Prof. R. O. Heinrich, Nikola Tesla and Dr. E. L. Nichols. Prof. Heinrich is already in Europe, and Mr. Hering sailed July 2 on the "Normannia." Mr. Tesla is not certain that he will be able to go. No further meetings of the Institute will be held until September.

Electrical Piano Test.—A number of well-known musical people and newspaper men met in one of the parlors of the Brunswick Hotel last week in response to invitations to a musical reception by an automatic electric piano company, which has recently been organized. Two upright pianos were in sight, and when the hour arrived at which the musical programme had been scheduled to begin no performers had put in an appearance. Among those who waited were Edmund C. Stanton, John McClair, Mrs. Goodwin, Mrs. C. Upton, Gen. and Mrs. Ferrero, and Mrs. John A. Cockerill. At length A. B. de Frece pressed an electric button, and on the instant there came from one of the instruments the notes of the march from Mendelssohn's "Midsummer Night's Dream." The keys of the piano worked up and down as they do when a musician presses them. Following the march came a selection from "Tannhäuser." It was as if an invisible hand were working the keys, and the effect was weird and uncanny. L. H. H.

NEW ENGLAND NOTES.

BRANCH OFFICE OF THE ELECTRICAL WORLD,
Room 8, Cook Building, cor. Franklin and Congress Sts.,
BOSTON, Mass., July 4, 1891.

The Lynn and Boston Railway has, it is reported, adopted the Westinghouse system for its line between Boston and Lynn, line to be equipped at once.

Newton, Mass.—The Board of Aldermen and Mayor of the city visited Beverly last Thursday, for the purpose of inspecting the Beverly & Danvers storage street railway.

Harvard Electrical Engineering Course.—At the reunion of the Lawrence Scientific school of Harvard yesterday it was announced that Mrs. Rotch had given the school $10,000 for an electric engineering workshop.

Mr. Collins McLeod, of New York City, for some time foreman of the Thomas Murray Company, which is now laying the rails for the electric road in Lawrence, was killed by a steam car at the crossing of the Boston & Maine Railroad in that city last Monday.

The Kennebunk (Me.) Electric Light, Heat and Power Company has organized with Sidney T. Fuller, president; Walter L. Dane, secretary, and Frank M. Ross, treasurer, Robert W. Lord, Charles R. Littlefield, Joseph Titcomb and William Moody will be the directors.

raphers' Aid Association.—On June 19 the employees of the New England Telephone and Telegraph Company organized what is to be known as the New England Telephone Employees' Mutual Aid Association. The association starts with 112 members. Following is a list of the officers: President, Geo. H. Dresser; vice-president, E. W. Mirrill; treasurer, J. A. McCoy; secretary, John F. Breen.

Mr. J. F. Denison has terminated his engagement with the Audobon Machine Works, and will in future be connected with the Denison Electrical Engineering Company, of New Haven, Conn., as electrican and general manager. While this company has been in business but a very short time it is able to report a prosperous business in various lines of electrical apparatus. The company is engaged in perfecting a motor especially adapted for alternating service, which will be placed upon the market in a short time.

The Friends of Eugene F. Phillips, president of the American Electrical Works of Providence, R. I., were last week reminded in a very unique way of the approach of Independence Day. A little package containing what purported to be a musical instrument was sent out to each of his friends, accompanied by the following directions: "Not caring to blow our own horn, and desiring to have you join the patriotic orchestra, we send cornet. Below we give the full musical score of "Yankee Doodle," "Hail Columbia," "America" and the "Star-Spangled Banner," as rendered upon this instrument. It is modestly requested that at the sound of the sunset gun 100 blasts be blown in honor of the American Electrical Works." The musical score referred to consisted of a single note.

The Boston and Revere Railway Company has been granted the privilege of running an electric railway from Winthrop Junction to Point Shirley by the selectmen of the town of Winthrop with the stipulation that it shall be completed early in July and be run all the year. This stipulation is made to protect a large number of permanent residents who do business in Boston, so that they may always rely on transportation facilities even though it did not pay the company to run its cars all winter. This line, if built, will be assured at once of a very large travel, as the road will take in a very thickly settled permanent resident district as well as running through a popular and rapidly growing summer resort the whole length of the line. The Boston, Winthrop & Shore road serves most of this territory now, but does not run to Point Shirley as the new road will do. C. A. B.

PHILADELPHIA NOTES.

BRANCH OFFICE OF THE ELECTRICAL WORLD,
31 CITY TRUST BUILDING, PHILADELPHIA, July 4, 1891.

Mt. Gretna, Pa.—The observatory surmounting Governor Dick. at Mt. Gretna, was struck by lightning during a heavy thunder shower on Wednesday night last and considerably injured. It is now undergoing repairs.

Meadville, Pa.—The Universal Fuel Company has placed one of its outfits in the city electric light station, and had it in successful operation last week. The idea is to burn crude oil and water, and certainly no hotter or more even fire than that furnished last week has ever burned under the boilers in question. The flame was shown to be fully under control and adjustable to almost any desired intensity. The electric light station was visited by many citizens who felt interested in seeing the trial, and a good many flattering comments were heard. The matter of expense is as yet experimental, but the company feels confident that it will be considerably less than either gas or coal.

The Year's Electrical Work in Philadelphia.—Mr. David R. Walker, Chief of the Electrical Bureau of the City of Philadelphia, has just issued his annual report for the year 1890, which is an admirable review of all of the electrical work done by the various electrical companies in the different city departments, including those of the telegraph, telephone, electric light, fire alarm, etc., during the year. The total expense for electric lighting, which is given as two-fifths of the total lighting expense of the city, was $201,259. There were on the streets of the city, Dec. 31, 1890, 6,623 poles used by telegraph, telephone and electric light companies, an increase of 1,128, and there were 5,309 city poles, an increase of 192, making altogether 11,932 poles. There were 4,314.23 miles of telegraph and telephone wires, 425.28 miles of electric light wires and 758 miles of city wires, making a total of wires on poles, fixtures and buildings of 5,557.51 miles, a decrease of 32.49 miles. There are 13,896 attachments to city poles.

WESTERN NOTES.

BRANCH OFFICE OF THE ELECTRICAL WORLD,
465 THE ROOKERY, CHICAGO, July 4, 1891.

Mr. J. A. Hanna, of the J. G. Brill Company, Philadelphia, Pa., is temporarily stopping in Chicago.

Mr. Frank Wunder, The Rookery, Chicago, has sold a 40-arc light Western electric plant to parties in Wheaton, Ill.

Mr. C. T. Combs, representing Westinghouse, Church, Kerr & Co., is in Chicago en route from Sioux City to Pittsburgh.

Captain C. C. Chadwick, 527 Phœnix Building, Chicago, is in the market for a dry battery for use in connection with train signaling.

Mr. Francis M. Ireland, who is well known among the electrical fraternity, has opened an office at 703 Owings' Building, Chicago, for the practice of patent law.

Mr. M. C. Chase, the hard rubber manufacturer, of Chicago, is bringing out a number of electric railway specialties that have given excellent satisfaction wherever tested.

Mr. Frank Wunder, of the Rookery, Chicago, Ill., has sold a complete 1,500 light Western Electric Incandescent plant to the Joseph Schlitz Brewing Company, of Milwaukee, Wis.

Mr. William Bowen, formerly manager of the Hawkeye Electric Company, of Davenport, and now representing the Thomson-Houston Electric Company, is in Chicago this week.

Mr. J. H. Shay, of the Charles Munson Belting Company, of Chicago, Ill., has sold 140 feet of a 54-inch double leather belt to the Evansville, Ind., Gas and Electric Light Company, this being in addition to the belts previously sold to the company.

Mr. Alexander Kempt, Western manager of the Brush Electric Company, has recently made some changes in his offices in the Temple Court building, Chicago, that add much to the convenience of the occupants and the handsome appearance of the rooms.

Mr. Payson Andrews, manager of the Chicago office of the J. G. Brill Company, of Philadelphia, Pa., has secured the order for eight 16-foot cars, with the Brill No. 7 truck, for street railway work at Jackson, Mich. Mr. Andrews is now in the East, but will return to Chicago early in July.

Mr. E. R. Gilman has resigned the presidency of all the electrical companies with which he has been connected, and will hereafter not take any active part in the management of these concerns, although he will remain on the board of directers. Mr. Gilman sails for Europe on the "City of New York" July 8.

Mr. William Compton, Vice-President of the Economic Electric Manufacturing Company, of Boston, Mass., is stopping at the Auditorium Hotel this week. During his stay in Chicago he complimented Mr. G. L. Kirkham on the large number of stations in the West that are now using the Economic incandescent lamp.

Prof. Elisha Gray has applied for 10,000 square feet space at the coming Columbian Exposition for exhibiting purposes. His exhibit will include a historical exhibit of all his inventions—hotel signals, printers' dials, telephones, harmony telegraph, etc. The principal part of the exhibit to be devoted to the Gray telauto graphic system of transmitting chirography and sketches.

Fair to be Open at Night.—It has been decided to open the Exposition nights. Every building is to be supplied with an electric plant, and the several miles of water in the lagoons and canals will also be lighted by electric lamps sunk beneath the surface. Landscape Architect Olmstead and John T. Barrett, chief of the Department of Electricity, were instructed to prepare a system of lighting both for necessary illumination and special features.

Mr. C. A. Brown, late manager of the Western Electric Company, Chicago, is now settled in the handsome suite of offices, Nos. 601 to 605 Temple Court, where the modest sign of Barton & Brown greets the many friends calling there. Mr. Brown's favorite office contains some richly upholstered furniture presented by his former associates in the Western Electric Company, all of whom, while regretting his change from a commercial to a professional life, wished him all the success that is certain to be won by a lawyer so industrious and persevering.

Messrs. McDougall and Cummings, the Western representatives of the Electric Construction and Supply Company of New York City, are meeting with excellent success in the introduction of the "Ward" arc lamp in the West, having sold some 200 lamps during the month of June. In connection with street railway lines, they are introducing the "Ward" lamp to burn ten in series, and each lamp supplied with an automatic resistance cutout, so that the current is automatically sent through the resistance should one or even five of the lamps be cut out of circuit.

Rapid Work.—On Friday afternoon, June 26, Mr. E. T. Burrell, manager of the Western department of Char. A. Schieren & Co., received a telegram from the Bay County Electric Light Company, Bay City, Mich., reading about as follows: "Burnt out; can you ship to-day 12-inch, 10-inch and 6-inch perforated belts?" Mr. Burrell wired his answer: "Yes; send lengths desired." At 5:30 P. M. the answer came, "Send four 12-inch, each 45 feet; two 10-inch, each 37 feet, and two 6-inch, each 25 feet in length." Owing to other sales that day the supply of perforated belting of the desired sizes was exhausted, yet these belts were taken from the rolls, perforated, packed and placed in the express car before 9 P. M. on Friday.

KANSAS CITY, Mo., June 30, 1891.

Mr. C. F. Clohesy, electrical engineer, is now quartered in the New York Life building.

Mr. J. W. Mason, formerly with Gate City Electric Company, has established himself at 527 Delaware street, and is doing a good business.

Mr. Rodney Ferguson, treasurer of the Missouri and Kansas Telephone Company, made a business trip to Leavenworth, Kan., last week.

Mr. G. Panteloni, Southern agent of the Westinghouse Electric and Manufacturing Company, with headquarters at St. Louis, Mo., was in the city last week.

The Gate City Electric Company at a recent reorganization meeting elected Wm. H. McKinlock president and W. D. Greene manager. The company reports business as being very brisk.

The Franklin Electric Company has secured a franchise at Red Oak, Ia., and will put in a $20,000 plant with both arc and incandescent equipment. This enterprising firm is putting in a large number of fans in this city, mostly alternating current.

The West Side Electric Railway Company, using the Rae trolley system and running from Wyandotte, Kan., to Quindaro, was placed in successful operation recently. The road is equipped with the latest improved rolling stock and has enjoyed a heavy traffic from the start.

The Western Electric Construction Company has moved into larger quarters at 125 West Fifth street. This company has just secured a contract for the construction of the Denver Suburban Railway, a line nearly 18 miles long, and 19 car loads of poles were shipped by the former company a few days ago.

Mr. A. Barrett, electrician of the Missouri and Kansas Telephone Company, has perfected a new protector, which is being largely adopted by his company. It is a marvel of simplicity, and has done some good work on its long lines. The company has 7,000 now in use. The Missouri and Kansas Telephone Company is trying to secure a franchise for underground conduits in this city, and if successful a mile will be constructed in the business portion. It is the purpose of the company to adopt the Chicago system, and to place the matter of construction in the hands of experienced men. There has been a vigorous agitation here for some time past against overhead wires, the principal objections being raised by the insurance companies. H. C. E.

MINNEAPOLIS, Minn., July 2, 1891.

Minneapolis is not through with having the streets torn up for conduit work. It was the hope of people in general that one system would do and thereby save the continual obstruction of the streets. The North American Telegraph Company commenced putting its wires under ground last week, and now the Brush Company, which has been the slowest in obeying the city ordinance, comes forward with the announcement that it, too, will commence work soon. There was a conference in the Mayor's office some days ago, between the Brush representatives and the city officials. They spent some time in convincing the officials that the company was doing all in its power to comply with the law. The company has received eight sealed bids for the installation of a complete underground plant. They were opened yesterday, and Mr. E. S. Corser and A. M. Robertson will go East and inspect systems in use by different bidders, after which work will commence at once. The electromotive force of the new plant will be 3,500 volts on the average, 2,000 volts and an alternating circuit and 500 on the power circuit. This is to be a good thing for the city, but it comes hard to have the streets all torn up again for another system of conduits. It seems that the streets will be in the same impassable condition they have been in for two summers past.

F. M.

SOUTHERN NOTES.

NORFOLK, Va., July 4, 1891.

Paris, Ky., contemplates putting in a fire-alarm system.

Atlanta, Ga.—The Grant Park Electric Railway Company is to build two miles of road.

Corpus Christi, Tex.—The Corpus Christi Electric Company has increased its capital stock to $10,000.

Colorado, Tex.—An additional dynamo is being placed in the Colorado Electric Light Company's plant.

Kosse, Tex.—It is reported that an electric light plant will be in operation here by the first of September.

Elkton, Va.—The Water Front and Amusement Company has been organized, and is to erect an electric light plant.

Memphis, Tenn.—The right of way for the building of an electric railway to Raleigh Springs has been asked for by W. R. Hall, of Chattanooga, Tenn., and Eugene T. Lynch, of New York City. The cost is estimated at $125,000.

Greenville, Tenn.—The electric light plant has been leased to Mr. H. Reaves. The capital stock will be increased to $10,000. The machinery for a complete alternating electric light system has been ordered from the Thomson-Houston Company. V. N. B.

ENGLISH NOTES.

(From our own correspondent.)

LONDON, June 24, 1891.

Electrical Standards Committee.—The proceedings of the Electrical Standards Committee, as was to be expected, are somewhat protracted, and only occasionally information leaks out as to what these proceedings amount to. A few months ago we had a memorandum setting forth what units it was proposed to adopt and the methods to be used in determining them, and a few weeks ago we were favored with a prescription for making the proposed legal standard cell, and now it seems that, among other things, it is proposed to appoint in certain towns inspectors for the express purpose of verifying and stamping electrical instruments. It is not stated, however, whether they are to be of the same order as the inspectors of weights and measures, and to pay surprise visits to places where they have reason to suppose incorrect instruments are in daily use.

The English Electrical Industry and Electrical Exhibitions.—At a meeting of the committee of the Electrical Trades Section of the London Chamber of Commerce on Monday last the attitude of the section toward the electrical exhibition at the Crystal Palace and that at Taunton came up for consideration, and there was a generally expressed opinion that this sort of thing was being much overdone. It was decided to make strenuous endeavors to obtain at least a postponement of the Crystal Palace Exhibition until next year. With regard to the Taunton show, it was felt that such a purely local concern did not come within the cognizance of the section. At the same meeting it was decided to circularize the members, with a view of visiting the Frankfort Exhibition in a body about the middle of September, the management of the exhibition having expressed themselves favorable to the idea.

Mutual Telephone Company.—The actual number of subscribers to this enterprising company's Manchester exchange is now about 400, and fresh ones are being added at the rate of 25 per week. After July 30 the magneto-transmitters now in use will be replaced by carbon ones made in accordance with one of Edison's figured in the "Tension Regulator" patent. After this date arrangements will be made to join up subscribers at the rate of 50 per week, and trunk lines to Bolton, Oldham and other important manufacturing Lancashire towns will be erected. Exchanges will also be opened in these towns. The Postmaster-General has been questioned once or twice of late in the House of Commons with a view of eliciting whether the Post Office have any idea of dropping their attitude of armed neutrality with regard to the National Company on and after the 30th of July next, when the Edison carbon transmitter patent will expire. So far the Postmaster Genera has succeeded in parrying these questions with highly diplomatic replies, giving no information whatever.

Central London Railway.—The bill for the construction of an underground railway some six miles in length, running from the city to the West End, came before a select committee of the House of Lords on Tuesday. The opposition was of a very feeble character. Several disinterested and independent witnesses gave most emphatic evidence in favor of the bill. Thus Sir Thomas Farrer, of the London County Council, said that he was satisfied as a private individual, a ratepayer and a public man, that the construction of the line would greatly relieve surface traffic, and he deemed the line a very important one for the inhabitants of London, and on these grounds he supported it. He thought that the opposition of the Oxford street shopkeepers was extremely selfish. Mr. Greathead and Sir Benjaman Baker gave evidence to the effect that the trains de the trip in 25 minutes, including stoppages, and that the cost per train mile was estimated at 9d. and the capital cost per mile for construction would be £600,000. After a brief consultation the committee decided this morning that the bill should be allowed to proceed.

Answers to Correspondents.

Questions to be answered in this column must be of general electrical interest, and must be accompanied by real name and address as a guarantee of good faith. No notice will be taken of questions regarding apparatus unless enough details are given to permit a definite answer, and no dynamo or motor designing will be done.

Electrical Statistics.—Will you kindly give me some electrical data with regard to the following questions? (1) What is the approximate mileage of telegraph wire in use in the United States and in the world? (2) What is approximate mileage of submarine cables in the world? (3) What is the mileage of telephone wire in the United States? How many subscribers? (4) How many electrical street railway systems in operation in the United States What is the mileage? (5) About how many arc lights and incandescent lights are in use in the United States? NASH.

We can give only a rough approximation as to the mileage of the various systems, and as to the number of electric lights in use (1) In the United States, about 776,500 miles. In the world, about 1,680,900 miles. (2) Something over 112,750 nautical miles. (3) Nearly 200,000 miles, with about the same number of subscribers. (4) Nearly 300 systems in operation. A rough approximation is 2,000 miles. (5) About 300,000 arcs and 3,500,000 incandescent lights.

Dynamo Action.—Will you kindly answer the following questions through your valuable paper? (1) How does the voltage of a dynamo vary in relation to the speed of the latter and in relation to the current strength in the field? (2) What work on winding, etc., would you recommend as a basis of instruction in the making of original instruments, dynamos, etc.? (3) With a small shunt-wound dynamo of standard make, could I practically regulate the voltage of the circuit by moderating the speed of the machine? C. F. E.

(1) The voltage or difference of potential between the terminals of the dynamo depends upon the rate of change in the magnetic intensity of the field in inductive relation to those wires of the armature which are being at the moment commuted. A change in the current exciting the field must necessarily produce a change in the magnetic intensity of that field, and therefore in the difference of potential between the ends of the wire "cutting" the lines of force of the field so changed. (2) Hering's "Principles of Dynamo Electric Machines," and perhaps Bottone's "Instrument Making for Amateurs." (3) With a small machine, yes.

News of the Week.

THE TELEGRAPH.

Lead City, S. D., is to have telegraphic connection with neighboring towns.

Milwaukee, Wis.—The Western Union Telegraph Company has won the first fight in the council by a report of the judiciary committee in favor of an amended ordinance granting the company the right to run its wires overhead in a cable instead of laying them underground.

The Rocky Mountain Telegraph Company is to build a line from Butte City, Mont., to Salmon City, via Bannack. The proposed line will cost about $5,000, and nearly half of that amount has been subscribed in three towns. Salmon has no way of communicating with the outside world except by mail.

San Francisco, Cal.—The Pacific Postal Telegraph Company has completed the changing of the terminus of its cable beween this city and Goat Island to the end of Clay street wharf. At the same time a new cable was laid between here and the island, and in about 10 days a similar cable will be laid from Goat Island to the foot of Seventh street, in Oakland. Last week L. W. Storror, superintendent of the company, made an inspection of the new line. The cost of the new cable was over $25,000. It is a particularly fine one. There are 10 separate conducting wires, which are covered by an armor of 12 No. 2 homogeneous galvanized-iron wires. The cable wire was made in England, but the armoring was done by the Roebling company. The new cable so far has been a success.

THE TELEPHONE.

Talmage, Neb., is at last in telephonic connection with the neighboring towns.

Benton, Ill.—The telephone line is completed, and the city is now in connection with Dubuque, Galena and other points.

Wyoming Lines.—The new telephone line between Silver Springs and Springville will very likely be installed this fall.

Brock and Worley, Pa., are putting forth an effort to have the Waynesburg and Blacksville telephone system line extended to the former points.

New Pennsylvania Lines.—The Indiana (Pa.) Telephone Company has recently added connections with the following points to its system: Decker's Point, Dixonville and Purchase Line, in the northern part of the county, and Homer, Graceton and Blacklick in the south. The latter line will eventually be extended to Blairsville.

THE ELECTRIC LIGHT.

Yazoo City, Miss., is to have electric light.

Hot Springs, S. D.—Work has begun on the new electric light plant.

Kenosha, Wis.—The work of installing the new electric light plant has begun.

Millville, N. J.—The new electric light plant is to be operated by water power.

Ploche, Nev.—The project of introducing the electric light is now under consideration.

Browntown, O., is to receive bids for an electric light plant and city fire alarm system.

Arkansas City, Ark., is considering the question of erecting a city electric lighting plant.

Berlin Falls, N. H.—An electric light plant is to be installed in the large paper and pulp mills now under consideration.

Oil City, Pa., was lighted by electric light last week for the first time, and the occasion was celebrated by a large number o citizens.

Loveland, Col., city authorities are now considering the establishment of an electric light plant to be erected within the summer or fall.

Harmon, Col.—The town board is to make a proposition to the electric light company of Montclair to supply the town with electric lights.

Joliet, Ill.—The electric light contract for lighting the city for the ensuing year has been awarded to the Joliet Economy Light and Power Company.

Oswego, N. Y.—The contract with the Oswego Light and Power Company has been renewed for another year, the village to pay for 63 arc lamps.

Florence, Ala.—The electric light plant and all attachments were sold at public sale last week and were sold at $7,469.90 by Mr. William P. Campbell.

Green Bay, Wis.—The new citizens' electric light plant is now operating 750 lights, and a long felt want of an all-night service is at last thoroughly supplied.

Camden, N. J.—The contract for electric lighting has been awarded to The Camden Heating and Lighting Company, which is to charge 39 cents per light per night.

Cheboygan, Mich.—A committee has been sent to Marquette to investigate the electric lighting system, with a view to deciding upon the city lighting question at Cheboygan.

California Isolated Plants.—The Edison Company has sold two 125-light plants to A. A. Osborne, of Benicia, Cal., and a 100-light plant to the Shasta Lumber Company, of Redding, Cal.

Aurora, Ill.—A movement is on foot among the East Side merchants to organize and start electric light plant of their own, if the price of light is raised by the present operating company.

Broadmoor, Col.—The electric light plant was completed last week and the lights turned on last week for the first time. A pretty sight now greets the eye on Cheyenne mountain at night.

The Western Light and Power Company, of Chicago, removed its office on July 1 to the power station, No. 1,227 Diversey street, at which address Mr. W. M. Talcott, the general manager, will conduct all future business of the company.

Bay City, Mich.—The power station of the Bay City Electric Light Company was destroyed by fire recently, which broke out in the fuel room. All the machiney, engines and dynamos were ruined, entailing a loss of $50,000, with insurance of $10,000.

Pittsburgh, Pa.—Mr. L. W. Sensabaugh, a Washington lawyer, and Mr. R. K. Warren, of Mobile, are at the Duquesne. Mr. Warren is a street railway owner, and he came on to inspect the Westinghouse electric system with a view to placing it on his line.

New Albany, Ind.—A short session of the New Albany Circuit Court was held last week, to make some disposition of the electric light plant. Judge Howk ordered that the entire plant be sold free of all encumbrances, with a stipulation that the plant be sold for not less than $40,000. The plant cost about $65,000. The sale will be made July 16.

THE ELECTRIC RAILWAY.

The First Electric Postal Line.—Mr. Lowry, of Minneapolis, Minn., has completed his arrangements with the government for the carrying of mail between St. Paul and Minneapolis on the electric railway.

The City Traction Company has been incorporated at Pittsburgh, Pa., to operate an electric street railway system. The line of this company, as projected, will cover a large portion of the East End district of the city as yet unprovided with rapid transit facilities.

Pittsburgh, Pa.—The Second Avenue Electric Railway Company has perfected arrangements for the erection of a bridge to cross the Monongahela River at Glenwood, five miles from the city. Upon the completion of this structure, the Second Avenue Company will extend its line to Homestead, four miles distant, and thus form an electric street car system about nine miles in length.

South Framingham, Mass.—The Framingham and Ashland Street Railway Company, a new incorporation with a capital stock of $60,000, is to build an electric road about five miles long. The following directors will act until others are legally chosen: W. B. Ferguson, Malden; C. H. Emerson, W. H. Pratt, F. E. Gregory and J. H. Goodell, Framingham; Thomas T. Robinson, Dedham; Adrian Foote, Ashland.

Rapid Work by the Baxter Company.—On the 8th of this month the Baxter Electric Motor Company, of Baltimore, Md., hisdepp three trucks with motors attached to Beatrice, Neb., and

on the 12th of the same month sent a generator of 80 h. p., and at the same time an electrician was sent from the works to erect the power-house and to put the road in operation. On the 30th of June the following telegram was received by the company: "Second car started June 27th, 11:30 P. M. Twenty-five hundred passengers Sunday without a hitch of any kind." The same company has a large number of orders for cars and motors to be installed in various cities of the South and West, and is shipping the equipment as rapidly as possible. Electric cars of this company's system are now running in Richmond, Va., Dayton and Cleveland, O., Chicago, Ill., Washington, D. C., and other places.

Connellsville, Pa.—The second electric street railway to be erected in the coke regions is to be built at Connellsville, extending through New Haven and Leisenring toward Uniontown, and is to be over five miles in length. The contract for the building of the road and the furnishing of motors and dynamos has just been let to the Edison General Electric Company, of Pittsburgh. The first road to be built was that at Uniontown, Pa., which was equipped with three cars and which covers a distance of several miles over steep grades. The Edison motors were selected for accomplishing this work, and upon the success of the road was dependent, in a measure, the building of the Connellsville and Leisenring line, for the reason that the object is to connect Uniontown and Connellsville by virtually the one street railway company. The building of the road has awakened much interest in the coke regions for the reason that it will be an enormous advantage to both Uniontown and Connellsville for the additional rapid transit between the various points and small towns located along the line.

GENERAL APPLICATIONS OF POWER.

Electric Coal Conveyance Plant.—At the coal yards of Mr. John M. Solomon, in Baltimore, Md., an electric conveyance plant has been in efficient operation for some time. The work is done in a most rapid manner, and is a proof of the adaptability of electric motive power for purposes of the kind.

A Large Electric Launch.—The Pacific Electric Storage Company reports the sale of an electric launch to Chas. S. Wieland, of San Francisco, Cal., to be run during the summer months on Lake Tahoe, and afterward on the bay. The dimensions are: length, 28 feet; beam, 6 feet; draught, 30 inches. The average speed will be about eight miles per hour, although it can be increased to 12 miles. The launch will carry 56 accumulators of the "23 M" type and a 4 h. p. motor, and will make a run of 70 miles on one full charge. It will also be equipped with a powerful search light, side lights, eight 16 c. p. incandescent lamps and an electrical fog horn. It will have seating capacity for 16. Mr. Wieland has also ordered a 4 h. p. gasoline engine, and an Edison dynamo for charging. This will be the first electric launch on the Pacific Coast.

LEGAL NOTES.

The Central Traction Company is the defendant in a suit brought by the city of Pittsburgh, Pa. One of the conditions under which the traction company received a franchise from the city was that before laying its tracks it was to pave the streets traversed by the tracks in a certain specified manner and within a certain specified time. The traction company failed to meet these conditions, and the city proceeded to pave the streets at its own expense. Afterward, the traction company desired to tear up the paving in order that it might place its tracks upon the streets, and was proceeding to carry on the work when the city brought suit to restrain it.

Trolley vs. Telephone.—The trolley decision in Ohio, of which we briefly spoke last week, was an injunction brought by the telephone company of Cincinnati, O., against the Cincinnati Inclined Plane Railway Company on the occasion of the latter's opening its electric line, which used a single overhead wire and a ground circuit. The telephone company was granted an injunction restraining the electric road from so operating. The lower courts decided against the railway, and it was only with the greatest difficulty that the railway secured an order of court to operate, pending the appeal to the Supreme Court, and on the filing of heavy bonds. The opinion of the highest authority in the State of Ohio is that the streets belong to the public, and are dedicated to travel, and that the rights of users of the telephone whose wires are in the streets are subordinate to the rights of travelers; that the electric railway is an improved conveyance, and that the telephone company has no vested rights in the ground circuit.

EDUCATIONAL NOTES.

University of Pennsylvania.—The university has decided to increase the time given to the subjects of mechanical and electrical engineering by providing additional courses in these subjects extending over four years. The courses, as at present established, extending over three years, will not be changed, and will require for admission that applicants pass the examination for entrance to college and the examinations of the freshmen and sophomore classes, and, as heretofore, special students properly prepared will be received on the same terms as at present.

PERSONALS.

Mr. Henry Villard, President of the Edison General Electric Company, arrived on Wednesday of last week from Bremen.

Mr. J. L. Barclay, of the Chicago, Ill., railway department of the Westinghouse Electric and Manufacturing Company, is again in the East on business.

Mr. John Tregoning, formerly superintendent of the Thomson Electric Welding Company's Works at Lynn, Mass., is now with Nicholson & Waterman, tool makers, Providence, R. I.

Mr. H. A. Royce, general manager of the Thomson Electric Welding Company, has just returned from Europe, where he went on business connected with the affairs of the International Welding Company.

Thomas B. Byrnes, Esq., aged forty-seven, for some time local manager of the Jenny Electric Light Company, died at Indianapolis, Ind., last week, from the effects of an apoplectic stroke sustained a few days before.

Mr. Hermann Lemp, of the Thomson-Houston Electric Welding Company, was in Johnstown, Pa., last week on business connected with the large plant of welders in use by the Johnson company at that place.

Mr. Sidney E. Short, of the Short Electric Railway Company, spent Sunday of last week with Mr. John S. Bartlett, of Lynn, Mass., vice president of the Brush Electric Company and treasurer of the Thomson-Houston Electric Company.

Mr. Carl Hering sailed for Europe, on Thursday of last week to attend the Frankfort Electrical Exhibition as the representative of THE ELECTRICAL WORLD and as chairman of the special committee of the Institute of Electrical Engineers.

Mr. E. W. Rollins, of the Denver (Col.) Consolidated Electric Company, is a visitor in Pittsburgh, Pa., this week. Mr. Rollins reports that his company is meeting great success in the extension of its business and expects to make some large increases to its capacity during the coming winter.

Industrial and Trade Notes.

Mr. C. H. Stoelting, 68 Canal street, Chicago, is supplying to several apartment-houses a clock device that at stated hours automatically lights the gas or extinguishes it in all the halls and rooms directly under the care of the janitor.

The Maxstadt Electric Company, 805 Owings Building, Chicago, is placing a fusible cut-out on the market, the fuse of which is guaranteed to "blow" as low as two-tenths of an ampère. Also a commutator compound that is said to do away with sparking at the brushes.

Messrs. Chas. A. Schieren & Co. have secured the order for six 13½-inch double perforated electric belts for the Consolidated Street Railway Company, of Columbus, O., and one 40-inch and five 12-inch belts for the Worcester, Leicester and Spencer (Mass.) Street Railway Company.

The Eureka Tempered Copper Company, of North East, Pa., has just issued a little pamphlet giving details regarding the material which it is placing on the market for various electrical uses, and containing testimonials from a large number of users as to the merits of this now quite common material.

Messrs. C. M. Rumrill & Co. have secured the contract for all the line appliances of the five miles of road now being built by the Syracuse (N. Y.) Consolidated Street Railway Company, and the Newark (N. J.) Rapid Transit Company, now building a road from Newark to East Orange. This company has also contracted with the Rumrill company for the wire and line material.

Handling of Fuel.—The question of handling fuel economically is an important one in the majority of both electric-light and street-railway plants, and central station managers should write to the Borden-Selleck & Co., 48 and 50 Lake street, Chicago, for the plans and specifications of their method of increasing the dividends of local companies by economically handling the fuel used.

The Illinois Electric Material Company, Chicago, has just placed in stock a handsome line of double and triple braided weatherproof wire known as the "Diamond I" brand, the insulation of which possesses remarkable qualities for toughness and durability, and in being impervious to moisture, while the finish is a smooth one and "as fine as silk," to use Mr. Hoefer's expression.

Mr. George T. Kirkham, of Chicago, has clearly demonstrated what can be done in placing a new incandescent lamp on the market through judicious advertising and close attention to the customers' needs, for within less than three months he has secured from one to ten customers in 85 different western towns and cities, all of whom are now using the Economic lamp in preference to any other.

Messrs. Taylor and Son, of 39 Dey street, New York City, will have ready for delivery in August a new battery containing *no zinc* or amalgam of any kind. The cell, it is claimed will give a voltage of one-quarter, and maintain 12 ampères on short circuit a considerable length of time. This battery will be marketed at a low price, and the sample cells are already attracting attention among those interested in electrical affairs.

The Holson Electric Harness and Supply Company, Dearborn street, Chicago, is arranging to place on the market the Holson device for stopping runaway horses. Connected to a dry cell placed in the carriage one wire passes to the bit in the horse's mouth, while a second wire is attached to a small metallic ball placed at the edge of the nostril. The shock following the closing of the circuit is found sufficient to divert the attention of the horses and to actually have cured two horses of the habit of running away.

Cutter's Mine Switches.—Mr. George Cutter, of Chicago, Ill., has brought out some waterproof switches and cut-outs for use in mines and tunnels, a large number of which are already doing good service. The presence of excessive dampness, and in some cases of running water, renders the ordinary devices useless in such places, and the good features of Cutter's mine switches and cut-outs will probably do much toward the extensive use of electricity in mines. Mr. Cutter is also working out some novel switchboard fittings and has just completed a slate base theatre switchboard which is as neat as it is serviceable.

The Barriett Electric Company, of 10 Cedar street, New York City, has just completed its new-style ⅛-h. p. motor, and it is now ready for the market. The machine has many features which will commend it, and the orders placed ahead are numerous This company has had a large trade on fan motors and has now about 125 of the motors in use in the city. The company is also building a new 7½-h. p. arc machine, which will be equipped with a new electric governor, the invention of Mr. Barriett. By the use of this governor a very steady current is obtained.

The Purity Oil Filter Manufacturing Company, of Pittsburgh, Pa., has received from the Louisville (Ky.) Street Railway Company the following letter, which speaks well for the oil-filtering apparatus of the Pittsburgh company: "Please ship us a 'Purity' oil filter same size as those in use by the Central Passenger Railway—a division of this company. We have seen the work of your filter, and are highly satisfied as to its efficiency." The Purity company also received a large number of additional orders from electric light plants in various parts of the country.

Facts about the Davidson Steam Pumps may be found in the small pamphlet recently issued by the M. T. Davidson Steam Pump Works, of Brooklyn, N. Y. The pamphlet contains illustrations and descriptions of the pumps, together with a very large and complete collection of letters from firms and companies using these pumps. Among the testimonials of interest to electrical people may be mentioned those from the Edison illuminating companies of Brooklyn and Rochester, N. Y., and Newport, R. I., and the one from the Field-Engineering Company, of this city.

The National Electrical Manufacturing Company, of 14 and 16 Vesey street, New York, has received the contract to install the Porter Electric Messenger Service, manufactured by it, in the new "Four Seasons" hotel and sanitarium just completed by the Cumberland Gap Park Company, Cumberland Gap, Tenn. There are 400 rooms in the hotel, and besides installing its messenger system the company will wire the hotel for a complete fire-alarm system, and also make connection by wire from the hotel to the railroad station. Two watchman's clocks of 12 stations each will complete the installation of what will be one of the best protected blocks of buildings in the country. The National company is meeting with great success with its messenger system, and it is now adopted by many of the leading hotels in the United States.

The Crowdus Primary Battery.—The Crowdus Chemical-Electric Company, of 230 Main street, Memphis, Tenn., has issued a catalogue giving details of the batteries it manufactures under the patents of Mr Walter A Crowdus. These batteries are intended for both constant current and constant potential service, and are claimed to be a decided improvement over the batteries generally in use for the operation of incandescent lights, electric motors and various other uses which call for more severe service in actual operation than most of the applications to which primary batteries are usually put. The batteries are made in four sizes and two different styles. The actual size of the smallest is 6¼ inches square and its weight 14 pounds when charged. The electromotive force of this cell is 7½ volts, its current 25 ampères, and its watt hour capacity 120. The largest size made has a hard rubber case which measures 12 × 13 inches, the electromotive force is 3.7 volts, its current 45 ampères and its capacity 1,200 watt hours. The maximum economical discharging rate is given as 15 ampères at 3 volts pressure. The cost of one charge including zinc consumed is said to be 55 cents, estimating materials at retail prices. This type of battery is designed for supplying incandescent lamps and motors for power purposes. The calculations of operating expenses are based upon sulphuric acid at two cents per pound, and amalgamated zinc at 10 cents per pound. At these prices it is claimed that the batteries of the Crowdus Company will produce 20 watts for an hour at a cost of one cent. There are only two exposed metal pieces on these cells; these are wholly outside the battery and are plated with either gold or platinum. The company states that in presenting the merits of its battery it desires it to be thoroughly understood that it is not entering into competition with the dynamo, that each has its field of operation and the one will create new uses for the other. The pamphlet contains full price lists of all the types of cells, together with motors and fans necessary for forming complete outfits for small power and lighting plants. The prices given range from the smallest outfit at $48 to the largest at over $300.

Business Notices.

Battery Cut-Out, Cheap.—Sensitive, reliable, never requires attention. Gas lighting much improved by its use. Electric Supply Co., of 105 South Warren street, Syracuse, N. Y.

Delightful Resorts.—Our readers who are desirous of finding pleasant places to spend the summer should bear in mind that the Chicago & Northwestern Railway furnishes every facility for a rapid, safe and comfortable journey from Chicago to Waukesha, Madison, Lake Geneva, Neenah, Marquette, St. Paul, Minneapolis, Duluth, Ashland, Lake Minnetonka, Yellowstone National Park, and the mountain resorts of Colorado and the far West. Fast vestibuled trains, equipped with reclining chair cars, parlor cars, palace sleeping and dining cars, afford patrons of the Northwestern every luxury incident to travel by a first-class railway. Excursion tickets at reduced rates and descriptive pamphlets can be obtained upon application to any ticket agent, or by addressing W. A. Thrall, General Passenger and Ticket Agent, C. & N. W. R'y, Chicago, Ill.

OUR ILLUSTRATED RECORD OF ELECTRICAL PATENTS.

U. S. PATENTS ISSUED JUNE 30, 1891.

454,867. Electrical Transmission of Telegraphic and Time Indications; Henry Jansen Haight, of New York. Application filed March 27, 1889. A multiple transmitter comprising a plurality of fixed contacts or electrodes, and a circuit closer adapted to bring said fixed contacts or electrodes one by one into electric connection with one pole of an electric generator, in combination with one or more indicating thermoscopes, one or more weather-indicating instruments, one or more wind-indicating instruments, or one or more time-indicating instruments, and one or more telegraph transmitting and receiving instruments for the purposes, all of which indicating instruments are in electric connection with the opposite pole of said electric generator, electric circuit wires connecting said indicating instruments with said several fixed contacts or electrodes respectively, and means for making and breaking the circuits between said indicating instruments and said fixed contacts or electrodes independently of said circuit closer.

453,873. Carbon for Electric Arc Lamps; Washington H. Lawrence, of Cleveland, O. Application filed April 9, 1887. A carbon rod for electric arc lights, having a compressed seamless spheroidal end.

454,881. Overhead Electric Conductor System; Gordon J. Scott, of Minneapolis, Minn., Assignor of one-half to Calvin G. Goodrich, of same place. Application filed Dec. 10, 1890. The combination, in a conductor contact system, of strips of plates adapted to pass on opposite sides of the conductor and adapted to electrically engage the same, means for drawing said contact strips along the conductor, the arms or brackets adapted to support said conductor, and means whereby said plates or strips are adapted to pass said arms without striking the same.

454,882. Electrodynamic Machine; Gordon J. Scott, of Minneapolis, Minn., Assignor of one-half to Calvin G. Goodrich, of same place. Application filed Jan. 2, 1891. In an electrodynamic machine, an annular iron ring field magnet having windings arranged in diametrically opposite pairs, with a flat bar or block of soft iron forming an armature adapted to revolve within said ring, a commutator provided in connection with the windings of said field-magnet ring, contact devices carried by said armature and adapted to make contact with said commutator, and connections passing from said brushes to revolving contact devices adapted to make contact with stationary brushes or contact rings, the branches of the working circuit being connected with said brushes or rings.

454,883. Motor Generator or Transformer; Gordon J. Scott, of Minneapolis, Minn., Assignor of one-half to Calvin G. Goodrich, of same place. Application filed Jan. 14, 1891. The invention consists in an annular iron field magnet ring having a suitable supporting base in combination with primary and secondary windings on said ring regularly disposed thereon, an armature adapted to rotate within said ring, and consisting in a bar or block of iron forming a diametrical path for the lines of force between opposite points in the field magnet ring, and brushes or other contact devices provided on said armature and adapted to rotate therewith and to press upon the surface of a suitable collector having its segments connected with the windings of said ring

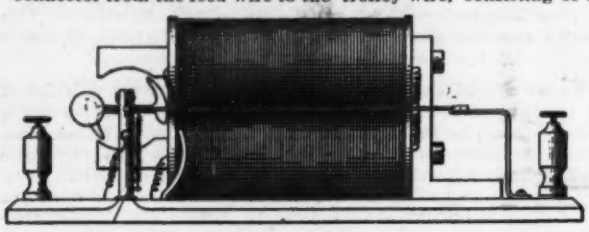
454,884. Printing-Telegraph Instrument; Frederick Sedgewick, of Chicago, Ill. Application filed June 1, 1886. The combination with a single main line and an electro generator of a series of rotary electric motors, each consisting of polarized magnets forming a cylindrical field, an armature within said

field having radial arms, a commutator for controlling the action of said armature, whereby the currents may be alternately reversed, a type wheel, and mechanical connection between said type wheel and armature.

454,888. Electric Car-Motor Jacket; John Stephenson, of New York. Application filed Dec. 12, 1890. A car with its electric motor incased, wholly or partly, with flexible vertical walls, with their upper and lower verges of rigid material, and thereby secured to the covering and to the bottom of the case.

454,890. Apparatus for Removing Inductive Effects from Electric Lines; Elihu Thomson, of Lynn, Mass., Assignor to the Thomson-Houston Electric Co., of Connecticut. Application filed April 8, 1889. The invention consists in setting up a counteracting field of induction, which operates upon both telephone circuits, each of which latter is arranged in a different portion of the field of counter-induction, but in position not to induce upon the other. (See illustration.)

454,903. Means for Connecting Trolley and Feed Wires; John R. Fletcher, of Chicago, Ill. Application filed Sept. 30, 1890. An electric-railway system having the combination of a trolley wire suitably supported and insulated from its supports, with a feed wire also supported and insulated, and a connector from the feed wire to the trolley wire, consisting of a



No. 454,926.—PROTECTOR FOR USE IN ELECTRIC CIRCUITS.

short conductor in contact with the feed wire, a curved piece connected with such short wire, and a downwardly depending contactor from such curved piece to the trolley wire.

454,904. Aerial Cut-Out; John R. Fletcher, of Dayton, O. Application filed Sept. 30, 1890. In cut-outs, a part consisting of a shank and a socket, both provided with apertures substantially concentric, but opening in opposite directions, the wire being soldered in the aperture in the shank, a non-conducting connector adapted to be inserted in the aperture in the socket, and a transverse bolt which passes through such connector and secures the same to the socket.

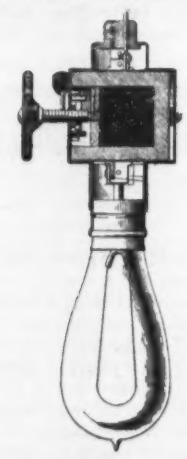
454,924. Hotel Indicator; Frank B. Wood, of New York, Assignor to Theodore W. Bayaud, of same place. Application filed Aug. 2, 1890. An indicating system comprising a normally closed main line, an indicator actuated by the current on the main line, a series of transmitters in circuit therewith in said main line, the messages all being transmitted over said main line, separate independent short-circuit lines extending from the transmitters and normally out of electrical contact with the main line, and a circuit breaker with which said lines are normally in contact and adapted to break said circuits when the current passes through one of said lines to cut out the short circuit and shift the current from the transmitters onto the main line to send in the call.

454,926. Protector for Use in Electric Circuits; Wm. H. Clausen, of Melrose, Assignor to Joseph W. Larish, Trustee, of Boston, Mass. Application filed Dec. 22, 1890. A protector consisting of an electromagnet having a coil of high resistance, with its armature and a movable arm and support, said arm and support being normally in electrical contact and in multiple with said electromagnet, and said arm being connected to said armature. (See illustration.)

454,938. Method of Laying Electric Conduits; Alexander C. Chenoweth, of New York. Application filed June 30, 1887. The method of forming continuous conduits, consisting in the preparation of the centering of the required shape and size by spirally winding a properly shaped core with the material out of which said centering is constructed, withdrawing the core, then sustaining the centering in position without its core, surrounding the centering with material out of which the conduit is to be constructed while said material is in a plastic condition, and, after the latter has hardened or set, finally withdrawing said centering.

454,939. Means for Constructing Electric Conduits; Alexander Crawford Chenoweth, of New York. Application filed March 7, 1891. The method of forming, shaping, or casting the interiors or concave surfaces of conduits, pipes, or castings, consisting in the preparation of a centering of the required shape and size by spirally winding a properly shaped mandrel or core with the material out of which said centering is constructed, sustaining the core and centering in position, surrounding them with material out of which the conduit is to be constructed while said material is in a plastic condition, and thereafter, and before said material has had time to set, withdrawing the core, and finally, after said material has set, withdrawing the centering.

454,949. Electric Meter; Herbert M. Pilkington and Roger S. White, of Brooklyn, N. Y. Application filed Sept. 26, 1890. The combination of a coil or magnet adapted for connection in



No. 454,969.—ELECTRIC CURRENT REGULATOR OR RHEOSTAT.

an electrical circuit, an armature moved thereby, a pivoted arm carried by the armature and moved thereby in one direction, a propelling pawl carried by the arm, a register moved by the pawl, and means for moving said arm in a second direction to advance the pawl and through the pawl the register.

454,969. Electric-Current Regulator or Rheostat; Charles D. Sigsbee, of the U. S. Navy, and Thos. S. Hayward and Frank S. Anderson, of Easton, Md.; said Anderson and Hayward assignors, by direct and mesne assignments, to said Sigsbee. Application filed March 10, 1891. A resistance for rheostats, composed of relatively long elastic fibres coated with a conducting substance. (See illustration).

454,973. Electric Signaling Apparatus; Morris Martin, of Malden, Assignor to Fred. P. Fish, of Cambridge, Mass. Application filed Nov. 5, 1888. The apparatus comprises a signal transmitter connected in circuit with a signal-receiving station and controlled as to its operation by a local circuit, the invention consisting mainly in novel features of construction of the said transmitting apparatus and in combinations and arrangements of the parts of said apparatus with the main circuit, connecting it with the signal-receiving station and with the local circuit by which it is controlled.

454,974. Circuit for Electric Signaling; Morris Martin, of Malden, Assignor to Fred. P. Fish, of Cambridge, Mass. Application filed Nov. 5, 1888. The invention consists in providing an automatic circuit changer or shifting device, which when the line is in normal condition—namely, unbroken—and having no ground connections upon it completes a main circuit through one battery and receiving instrument and all the out stations, and at the same time retains another battery closed in a local circuit containing a high resistance, so as to prevent rapid consumption of said battery.

454,979. Electric Heater; Chas. W. Drew and Edward R. Francismof, Minneapolis, Minn; said Francis Assignor to said Drew. Application filed Feb. 20, 1890. In an electric heater, the combination, with a suitable casing, of an electric heating-resistance arranged within said casing and connected with said heating resistance, and a switch whereby any number or all of the coil of the rheostat may be cut out.

454,995. Electric Switch; James Des Brisay. Application filed Dec. 10, 1890. A switch having a base provided with beveled holes and two or more beveled binding posts, each having a longitudinal slot, in combination with switch-electrodes adapted to fit in said slots and having lateral bearing upon the inner face of the switch-base, each binding post being provided with an adjusting screw adapted to securely bind it to the base.

455,005. Circuit-Closer for Burglar Alarms; Don A. Palmer, of Chicago, Ill. Application filed May 26, 1890. In a circuit-closer having a framing casting provided with slots, a cord-pulley adapted to revolve under a suitable shaft in said slots as in bearings, and an insulated spring-contact secured upon said casting, whereby contact will be made or broken when the said pulley is revolved by the sash-cord moving over the same.

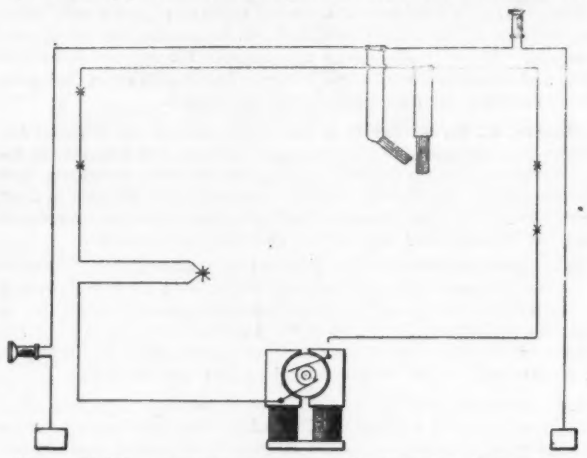
455,010. Electric Soldering-Iron; Arthur E. Appleyard, of Boston, Assignor to Henry L. Millis, Trustee, of Millis, Mass. Application filed Oct. 1, 1890. An electric soldering-iron, having a hollow metal shell, a conducting-loop arranged in curves or corrugations within the shell, the curves of one part of the loop extending in a different direction from the curves of the other part, and a filling of refractory non-conducting material supporting said loop.

455,016. Electrical Annunciator; Wm. F. Harte and Clifford A. Gerold, of Omaha, Neb., said Gerold Assignor to said Harte. Application filed March 28, 1891. An electrical communicator having a case with circuit wires detachably connected with the dial and a driven hand adapted to engage contact posts and close the electric circuit.

455,019. Circuit-Connection for Electric-Car Motors; Arnold A. Ingraham, of New York. Application filed Nov. 18, 1889. The combination with an electric motor for a car and secondary batteries, of two ranges of contact-blocks, one near each end of the car, two cylinders and ranges of circuit-connecting devices, for bringing into action more or less electromotive force, and wires leading to the commutator-brushes and transposed in position in the two ranges of contact blocks, so that the motor is rotated in either one direction or the other, according to which one of the cylinders is made use of.

455,041. Electric Clock for use in Electric Lighting and other Systems; Freiedrich Von Hefner-Alteneck, of Berlin, Germany. Application filed Feb. 25, 1891. The combination, with an electric circuit—such as the circuit of an electric lighting plant—of an electromagnet included in the circuit, a vibratory armature provided with a device for setting the clock, the said armature being adapted to be retained by the said magnet when passed in contact with it and while the potential of the current is normal, and an automatic operating device, such as a spring, adapted to actuate the clock-setting device when the said armature is released from the magnet by a variation in the potential of the current.

455,055. Electric Time-Denoting Device; William Ramsay, of Washington, D. C. Application filed Jan. 15, 1891. The invention consists in combining in an electric circuit a mechanic-



No. 454,890.—APPARATUS FOR REMOVING INDUCTIVE EFFECTS FROM ELECTRIC LINES.

ally operated main clock mechanism, and a circuit-controlling device actuated by said clock-mechanism, with electromagnets in the circuit located adjacent to or around a supplementary time face at a distance from the main clock to acutate an armature carrying a pointer, whereby a variable current is caused through the electromagnets and the armature actuated to move the pointer.

455,067. Electro-magnetic Motor; Nikola Tesla, of New York. Application filed Jan. 27, 1891. In an alternating-current motor, the combination, with the field magnets and energizing circuit, of an armature circuit and a core adapted to be energized by currents induced in its circuits by the currents in the field circuit, and a condenser connected with the armature circuit only.

455,068. Electrical Meter; Nikola Tesla, of New York. Application filed March 27, 1891. The method of computing the amount of electrical energy expended in a given time in an electric circuit, which consists in maintaining by the current a potential difference between the two conductors in an electrolytic solution uniform throughout the whole extent of such conductors exposed to the solution and measuring the variation of the resistance in one or both of said conductors exposed due to the gain or loss of metal by electro deposition. (See illustration.)

455,069. Electric Incandescent Lamp; Nikola Tesla, of New York. Application filed May 14, 1891. An incandescent lamp consisting of two isolated refractory conductors contained in a non-striking vacuum and adapted to produce light by incandescence, each being provided with a terminal for connection with a source of electrical energy. (See illustration.)

455,071. Clutch for Arc Lamps; Frank H. Thompson, of Philadelphia, Pa., Assignor of one-half to Daniel Killion, of same place. Application filed Oct. 18, 1890. A clutch for an arc lamp, having a lever with an adjustable jaw thereon and a base with an adjustable jaw opposite the said adjustable jaw or lever, said jaws being horizontally arranged and slotted and having their opposing edges adapted to engage with an inserted carbon-rod.

455,075. Printing-Telegraph; Henry Von Hoevenbergh, of New York, Assignor to the Equitable Manufacturing and Electric Company, of same place. Application filed Feb. 24, 1891. The combination of a rotatable type wheel, a segment wheel, transmitting keys connected with the individually insulated segments of the segment wheel, a trailer moving with the type wheel and traversing the segment wheel, a neutral relay, the trailer and relay being connected with the main line, a type-wheel-controlling magnet, a press magnet, and two local circuits respectively connected with the front and back stops of the relay and both connected with the relay-armature lever, the type-wheel magnet and press magnet being both included in both local circuits.

55,087. Electric Arc Lamp; Craig Ritchie Arnold, of Chester, Pa. Application filed May 28, 1890. In an electric arc lamp, a lower-carbon holder and globe or shade therefor, both supported on a sliding or adjustable frame or carrier adapted to be raised or adjusted above the position occupied when carbons of normal length are employed, and means for setting or fixing the frame and supported carbon and globe in any desired vertical position.

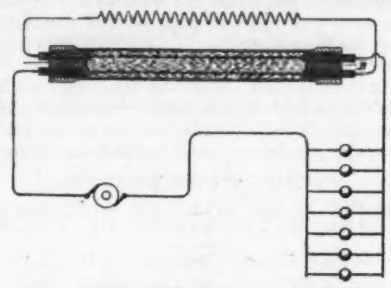
55,092. Automatic Electric Switch; Carl O. C. Billberg and Paul A. N. Winand, of Philadelphia, Pa. Application filed Nov. 11, 1890. A time-switch for electric circuits, consisting of a contact-chamber containing electrical contacts at different points therein and adapted to be connected with resistances, with a mercury reservoir connected to the contact-chamber, a device for throttling the passage between the reservoir and the chamber, and means uncontrolled by the circuit to cause a determined quantity of mercury to flow into or out of the chamber.

55,107. Insulator; James F. Munsie, of Brooklyn, N. Y. Application filed March 28, 1890. An insulator, consisting of a base and an overhanging cap piece, said base being provided at its upper surface with a filling of hygroscopic material.

455,109. Electric Motor; Frederick L. McGahan, of Indianapolis, Ind. Application filed Feb. 11, 1891. An electric motor comprising a main wheel loosely mounted on an axle having bearings in the frame-work, its inner face providing a friction-surface, a series of dogs passing through coils, a revolving shaft supported within the main wheel, these dogs provided with insulated surfaces, commutators carried on collars revolving with such shaft, brushes connected with the wires of the main circuit and the commutators connected with the wires of the coils, whereby the force of the current combined with that of the pressure-plate operates to thrust the dogs outward to contact with the inner face of the main wheel for revolving the same.

455,110. Electric Motor; Frederick L. McGahan, of Indianapolis, Ind. Application filed Feb. 16, 1891. In an electric motor, a wheel to be driven, loosely mounted on an axle supported in bearings upon a frame work, the periphery of such wheel grooved or corrugated, a counter-shaft supported in bearings at one side of the wheel, two or more coils passing through such counter-shaft and provided with corrugated or grooved heads forming dogs for engaging with the grooves of the main wheel, and a suitable electric connection for thrusting the dog outward to a position where the gravity of the dog will operate as a lever to drive the main wheel.

455,138. Electric Signal for Steam-Vessels; Dyson D. Wass, of San Francisco, Cal., Assignor of one-half to Edwin W.



No. 455,068.—ELECTRICAL METER.

Tucker, of same place. Application filed Jan. 5, 1891. In an electric indicator, the combination, with a series of variable signal-transmitters, of a compound rotatable handle, the pivoted member carrying a horizontally extending locking pin or bolt, and at its lower end a rotatable and longitudinally movable shaft having a contact-making and breaking arm connected therewith, said shaft being carried rearward in order to make and break the circuit when the upper ends of the handles are pressed together.

455,176. Apparatus for Automatically Regulating the Firing of Ordnance on Ships; Manuel Jose Cuadros, of Leige, Belgium. Application filed Aug. 27, 1890. The combination, with a vessel and a gun thereon, of a pendulum suspended from a part thereof and having a conductor for electrically connecting with one pole of a generator or battery, a post standard or frame having a suitable lever carrying a vertically movable contact point located beneath the lowest point of the pendulum and having an electric conductor, and means for moving the lever to elevate the contact pin for the purpose of making contact with the pendulum to close an electric circuit, which includes the charge in the gun, for firing the latter when the vessel is in its normal position.

455,187. Filament for Incandescent Electric Lamps; George Erlwein, of Berlin, Germany, Assignor to Siemens & Halske, of same place. Application filed Feb. 18, 1891. In incandescent lamps a glow body consisting of a carbon filament for a core, and a coating of nottrieds of boron incasing the core.

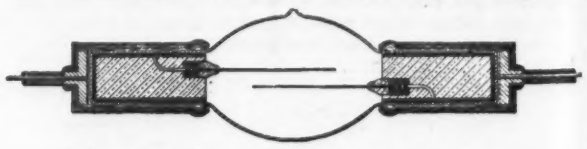
455,223. Lightning-Arrester; Frank Mansfield and Charles W. Wason, of Cleveland, O. Application filed July 22, 1890. A lightning-arrester comprising a ground connection having a series of branches, each branch having a so-called "safety-strip" connected therewith, and intervening space incapable of permitting the passage of a normal current, of a gravity lever electrically connected with the electric-wire system, such gravity lever being adapted to rest successively on the different safety strips, each safety strip in turn serving as a stop to limit the descent of the gravity lever.

455,233. Electric Railway; James F. Munsie, of Brooklyn, N. Y. Application filed May 8, 1891. An electric railway comprising an underground feeding conductor, a series of branch conductors extending therefrom and separated by intervening spaces, overhead contacts normally out of electrical connection with said branch conductors, and a bar mounted upon the car and in the motor circuit of the car, said bar being adapted to bring said contacts successively into electrical connection with the branch conductors.

455,234. Electric Railway; James F. Munsie, of Brooklyn, N. Y. Application filed May 8, 1891. In an electric railway, the combination, with the feeding conductor, of a trolley-track consisting of a series of sections suspended in an upright position and adapted to swing downwardly.

455,266. Electric Railway Signal; Winslow Stevens and Henry J. Hovey, of New Haven, Conn., Assignors to the Hall Signal Company, of Portland, Me. Application filed Nov. 11, 1890. In an electric railway system, the combination, with a blocking and a clearing circuit, both emanating from the same battery, of a short circuit for said battery, and a magnet in the clearing circuit controlling said short circuit, and a second battery in the clearing circuit.

455,267. Automatic Regulator for Electric Motors or Dynamo-Electric Machines; Schuyler S. Wheeler, of New York, Assignor to the Crocker-Wheeler Motor Company, of same place. Application filed Nov. 8, 1890. A dynamo-electric machine or electric motor having the effective magnetic portions of its field magnets and armature of substantially equal magnetic capacity, and so wound as to produce like polarity and an equal opposing effect between said field magnet poles and those portions of the armature core which are being magnetized at the time that the brushes are passing over consecutive segments of the commutator, in combination with an automatic regulator



No. 455,069.—ELECTRIC INCANDESCENT LAMP.

adapted to shift the brushes and maintain the aforesaid magnetic balance.

455,287. Socket for Incandescent Electric Lamps; Benjamin B. Keyes, of Chelsea, Mass. Application filed Oct. 6, 1890. The invention comprises a block of insulated material impervious to moisture, having recesses in opposite ends thereof separated by a partition, one of the recesses being used for the reception of the base of an incandescent lamp, a disc of hard rubber or other similar insulating material capable of holding a screw placed in the other recess, and firmly clamped to the partition, metallic contacts in the recess which receive the lamp, mechanically secured to the partition without cement and electrically connected to one of the conducting wires, a central metallic screw insulated for these contacts, and passing through the insulating disc and partition and projecting into the recess which receives the lamp, and electrically connected to the other conducting wire, and a filling of waterproof insulating cement in the recess which contains the insulating disc and conducting wires.

455,294. Printing Telegraph; David Bates and Henry Van Hoevenbergh, of New York. Application filed March 4, 1891. The combination of two series of letters or characters rotating in fixed relation to each other and having corresponding letters arranged side by side, a paper ribbon of sufficient width to receive impressions from both series of letters and provided with a longitudinal line of perforations or indentations to facilitate its longitudinal division into two ribbons, and impression devices for simultaneously printing on the ribbon from both series of letters duplicates of a message on opposite sides of the line of perforation.

Copies of the specifications and drawings complete of any patent mentioned in this record—or of any other patent issued since 1836—can be had for 25 cents. Give date and number of patent desired and address The W. J. Johnston Co., Ltd., Times Building, N. Y.